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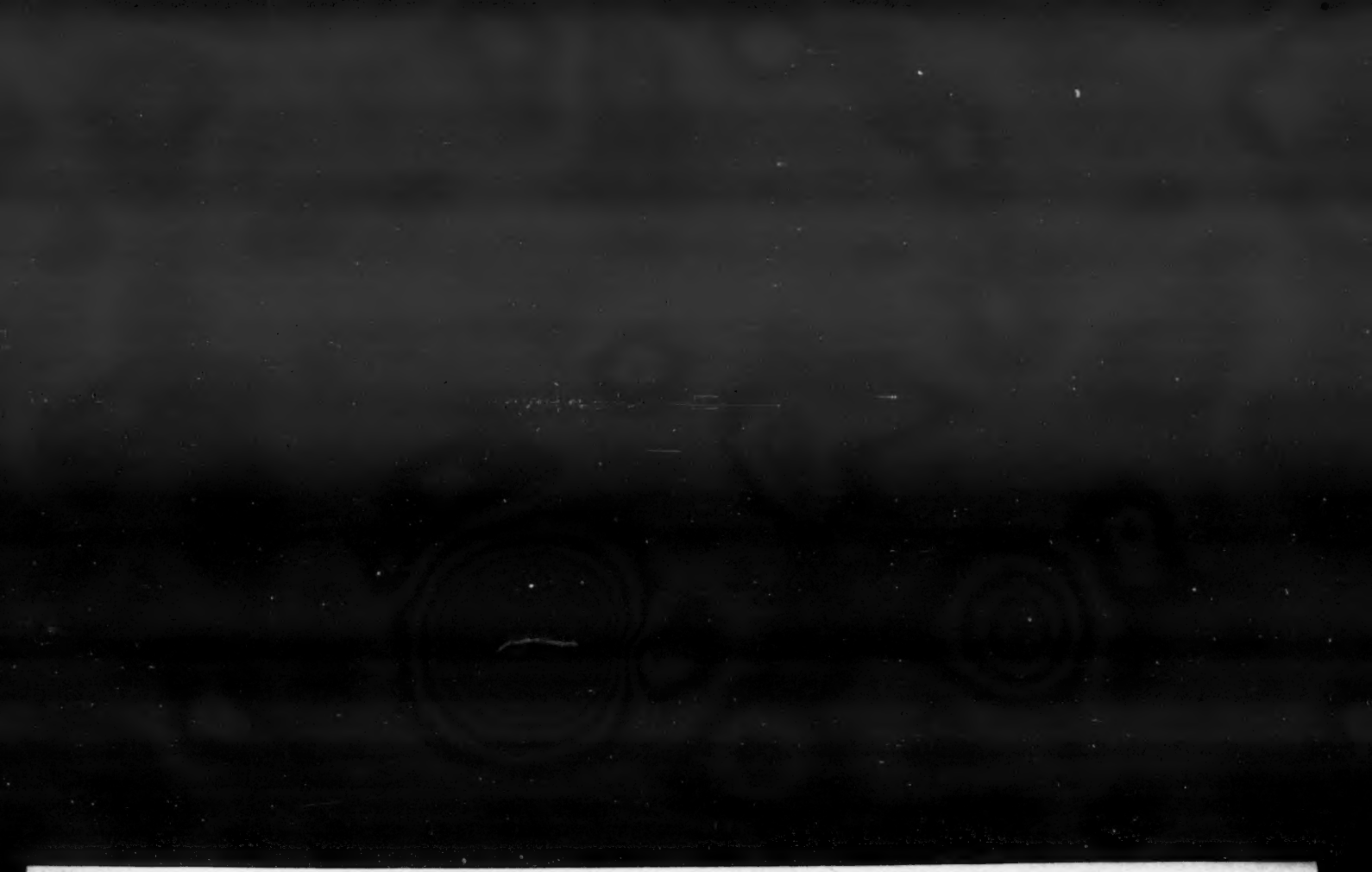

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XI.—*Researches in Acoustics;* by ALFRED M. MAYER.

Paper No. 10 containing The Variation of the Modulus of Elasticity with Change of Temperature as determined by the Transverse Vibration of Bars at Various Temperatures. The Acoustical Properties of Aluminum.
[Read before the British Association, at Oxford, Aug., 1894.]

Summary of the Research.

POISSON in his *Traité de Méchanique* (Paris, 1833, t. II, pp. 368–392)* discusses the laws of the transverse vibrations of a bar free at its ends and supported under its two nodes. He shows that the frequency of the vibrations of the bar is given by an equation, which, reduced to its simplest expression, is $N = V \times 1{\cdot}0279 \frac{t}{l^2}$; in which N is the number of vibrations per second of the bar, t its thickness, l its length and V the velocity of sound in the direction of the length of the bar.

To ascertain how near the frequency of the transverse vibrations of a bar, computed by Poisson's formula, agrees with the result obtained by experiment, the following method of experimenting was used.

Rods of steel, aluminum, brass, glass and of American white-pine (*Pinus strobus*)—substances differing greatly in their moduli of elasticity, densities and physical structures—were carefully wrought so as to have the length of $1{\cdot}5\pm$ meter; the thickness of $0{\cdot}5^{cm}$, the width of 2^{cms}, and a uniform section throughout their lengths. The velocity of sound in these rods was determined by vibrating them longitudinally at a temperatute of 20°, while held between the thumb and forefinger, and

* See, also, The Theory of Sound, by Lord Rayleigh, 1894, vol. i, ch. 8.

their frequencies of vibration ascertained by the standard forks of Dr. R. Kœnig's tonometer.

Out of each of these long rods were cut three bars of the length of 20^{cms}, and these bars, also at 20°, were supported on threads at their nodes, vibrated transversely by striking them at their center with a rubber hammer, and their frequencies of vibration determined by the forks of the tonometer.

The mean departure of the observed from the computed numbers of transverse vibrations (see Table I) is $\frac{1}{328}$; the computed frequency being always in excess of the observed, except in the case of glass, where the computed is $\frac{1}{275}$ below the observed frequency.

In Table I, l = length and t = thickness of bar in centimeters at 20°. V = velocity of sound in centimeters in bar at 20°. N = number of vibrations per second at 20°.

The close agreement of the computed and observed values shows that, by vibrating a bar at various temperatures, the variation of its modulus of elasticity with change in its temperature can be obtained. We observe, N, at various temperatures of the bar; then $V = \frac{N}{1{\cdot}0279\frac{t}{l^2}}$ is computed, and the modulus $M = \frac{V^2 d}{g}$.

As t, l, and d (the density of the bar), vary with the temperature, the coefficient of expansion of each bar and its density at 4° were determined, so that the dimensions and density of the bar could be computed for each of the temperatures at which it was vibrated.

Experiments were made on five bars of different steels, on two of aluminum, on one of St. Gobain glass, one of brass, one of bell-metal, one of zinc and one of silver. The results of these experiments may be summed up as follows:

The modulus of elasticity of	St. Gobain glass	is	1·16	per ct.	less at 100°	than at 0°.
"	"	the five steels	" 2·24 to 3·09	"		"
"	"	brass	" 3·73	"		"
"	"	bell-metal	" 4·3	"		"
"	"	aluminum	" 5·5	"		"
"	"	silver	" 2·47	"	60°	"
"	"	zinc	" 6·04	"	62°	"

The decrease of the modulus of elasticity of glass, aluminum and brass is proportional to the increase of temperature; straight lines referred to coördinates giving the results of experiments on these substances. The five steels, silver and zinc give curves, convex upwards, showing that the modulus decreases more rapidly than the increment of temperature; while bell-metal alone gives a curve which is concave upwards; its modulus decreasing less than the increment of temperature. (See fig. 5, p. 95.)

The more carbon a steel contains the less is the fall of its modulus of elasticity on elevating the temperature of the steel. Thus, the modulus of the steel with 1·286 per cent of carbon is 2·24 per cent less at 100° than at 0°, while the steel containing 0·15 per cent of carbon has a modulus at 100° which is 3·09 per cent lower than its modulus at 0°.

So far as experiments on a single steel containing nickel permits of any general deductions, it appears that the presence of nickel in a low carbon steel lowers its modulus of elasticity. Thus, steels Nos. 3 and 4 having respectively ·47 and ·51 per cent of carbon have a modulus of 2131×10^6, while steel No. 5, containing ·27 per cent of carbon and 3 per cent of nickel, has a modulus of 2080×10^6, which is 2·12 per cent. lower than that of steels Nos. 3 and 4.

The presence of nickel in a steel may, in a diminished degree, have the effect of carbon in lessening the lowering of the modulus when the temperature of the steel is increased. Thus, the percentage of the lowering of the modulus, by heating from 0° to 100°, of steel No. 5 containing 0·27 of carbon and 3 per cent of nickel, is the same as that of steel No. 3 with 0·47 per cent of carbon.

If a bar of any one of the substances experimented on is struck with the same energy of blow, by letting fall on the centre of the bar a rather hard rubber ball from a fixed height, the sound emitted by the bar diminishes in intensity and in duration as the temperature of the bar is raised. Thus:

Brass	at 0°	vibrates during	75	secs.; at	100°	it vibrates during	45 secs.
Bell-Metal	"	"	55	"	"	"	15 "
Aluminum	"	"	40	"	"	"	12 "
J. & C. Cast Steel	"	"	80	"	"	"	5 "
Bessemer Steel	"	"	45	"	"	"	1·5 "
St. Gobain Glass	"	"	6	"	"	"	3·5 "

Zinc at 0° vibrated during 5 secs.; at 20° only during 1·5 secs. At 62° it vibrated for so short a time that it only gave three beats with forks of 1090 and 1082 v. s. At 80° it was not possible to determine the pitch of the bar, and at 100° the bar when struck gave the sound of a thud. The bar of silver acted in a similar manner to the bar of zinc—it was even less sonorous than zinc—thus flatly denying the "silvery tones" attributed to it.

These phenomena do not depend on the fall of modulus but on changes in the structure of the metal on heating, which cause the blow to heat the bar and not to make it vibrate.

Bell-metal was found to be an alloy peculiarly well suited for bells, as the intensity and duration of its vibrations were the same at 50° as at 0°; all other substances showing a marked diminution of intensity and duration of sound at 50°.

A bar of unannealed drawn brass, after it has been heated to 100°, has its modulus increased $\frac{3.6}{100}$ per cent. See Table III and fig. 11, p. 98.

In this research I had the good fortune to have had the assistance of Dr. Rudolph Kœnig, of Paris. He not only placed at my service the resources of his laboratory and workshop, but generously gave me constant assistance during the experiments; making the determinations of the numbers of vibration of the rods and bars with the standard forks of his tonometer. Without his aid this work could not have been done. For instance, in the cases of the bars of silver and zinc the beats they give with a fork are so few that they cannot be compared with a chronometer; but Dr. Kœnig, from his long experience in the estimation of beats, was enabled to form an accurate judgment of their number per second from the *rhythm* of the beats. The determination of pitches extending through such a range of vibrations as occur in this research can only be made with Dr. Kœnig's "grand tonomètre," a unique apparatus of precision, giving the frequency of vibrations from 32 to 43690 v. s., and really indispensable to the physicist who would engage in precise quantitative work in acoustics.

We now proceed to give accounts of the several operations performed in the progress of this research.

Determination of the Velocity of Sound in Rods.

In the determinations of the velocity of sound in the rods of 1·5 m. in length I used the method of Chladni.* Kundt's method of obtaining nodal lines of fine powders in a tube, by vibrating a rod whose end carries a cork which fits loosely the end of the tube, is not accurate. The weight and friction of the cork, the necessity of firmly clamping the rod at a node, and, above all, the want of knowledge of the velocity of sound in the air of glass tubes of different diameters, renders this method, so beautiful and ingenious, worthless for accurate measures of the velocity of sound in solids.

The curves in fig. 1 show the very diverse determinations of the velocity of sound in the air in tubes of different diameters by the physicists Kundt†, Schneebeli‡, Seebeck§, and Keyser‖. The velocity of sound in metres is given on the axis of Y; the diameter of the tube in centimeters on the axis of X. Ku stands for Kundt, Sch for Schneebeli, Se for Seebeck, and Ke for Keyser. The most precise measures of

* Traité d'Acoustique, Paris, 1809, p. 318 *et seq.*
† Bericht. der Akad. der Wiss. zu Berlin, 1867.
‡ Pogg. Ann.. 1869, vol. cxxxvi.
§ Pogg. Ann., 1870, vol. cxxxix.
‖ Wied. Ann., 1877, vol. ii, p. 218.

velocities are those of Keyser, who closed the end of the tube with a cork attached to the end of a steel-bar, while the other end of the bar was securely clamped. The frequency of the transverse vibrations of the bar was registered by a style describing the sinusoids of the vibrating bar. Thus the

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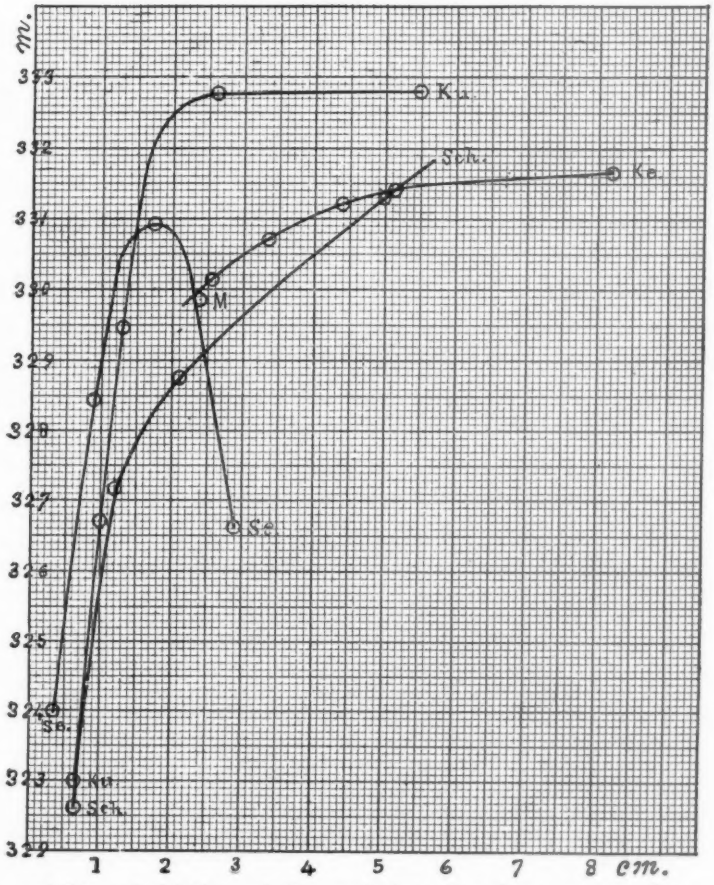


weight and friction of the cork introduced no error. In a similar manner I obtained the velocity, marked M in fig. 1, by vibrating a rod of aluminum. The frequency of the vibrations of the rod were measured while the cork at the end of the rod was vibrating in the mouth of the tube. The result agrees closely with Keyser's. It is needless to discuss the curves of fig. 1.

The method of Chladni, used exactly as that eminent man used it, remains the best we have. It is important, however, to note that the rod must be held between the thumb and forefinger when it is vibrated and not *clamped* when vibrated. When clamped it always gives a higher frequency, as shown by the following experiments:

Steel rod clamped	3429·2	Aluminum rod clamped	3377·0
Steel rod held between fingers	3428·4	Aluminum rod held between fingers	3376·4

The frequency of the vibrations of the rods of steel, brass, aluminum, glass and pine wood, when held at the middle of their lengths and vibrated so as to give their fundamental tones, gave exactly the octaves of these fundamental tones when held at one-quarter of their lengths and vibrated.

Determination of the lengths of the long rods and of the lengths and thicknesses of the bars.

The lengths of the rods of 1·5± meters were ascertained by comparison with the rod of steel whose length was measured at the Bureau International des Poids et Mesures. The lengths and thicknesses of the bars which were vibrated transversely were measured with micrometer calipers. The readings of these calipers were tested by comparison at 20° with a series of standards of various lengths of inches and fractions of inches, made for me with great care by Mr. George M. Bond, who has charge of the gauge department of the Pratt, Whitney Co. In reducing the comparisons to centimeters I adopted the value of the inch as equal to 25·4 millimeters. In obtaining the length of a bar, the mean of several measures in the axis of the bar and in directions parallel to the axis and at various distances from it was adopted. The thickness of a bar was taken as the mean of measures taken throughout the length of the bar at points designated by the intersections of lines drawn parallel and at right angles to the axis of the bar.

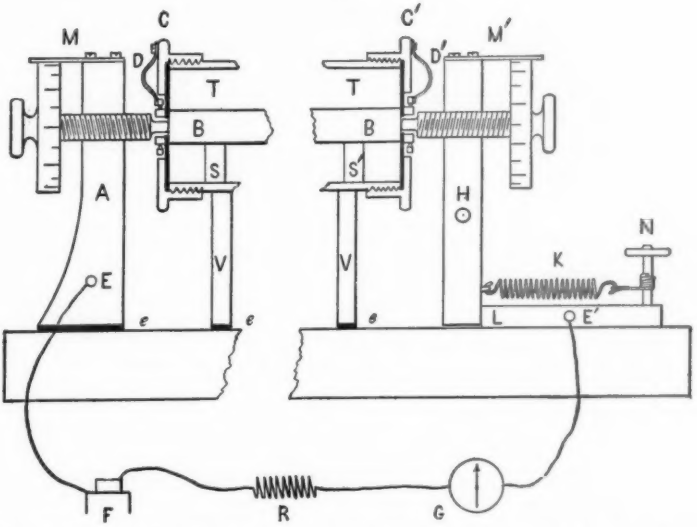
The dimensions of the bars were measured at 20°, except those of steels Nos. 3, 4, 5, which were measured at 18°·25.

Determinations of the Coefficients of Expansion of the Bars.

To determine the coefficients of expansion of the bars I devised the apparatus shown in fig. 2. In a brass tube, T, the bar, B, rests in slots in the supports, S, S′. The tube, T, is slightly shorter than the bar, B. Washers of rubber (shown in black in the figure), of the same diameter as the outside diameter of the tube, are placed in the screw-caps, C, C′. These washers are perforated with holes of diameters smaller than the thickness of the bar. When the caps are screwed up

the rubber washers press against the ends of the bar. This pressure is further increased by flat rings which surround the holes in the washers and are pressed against these washers by means of the springs, D, D′. By this arrangement the surfaces of the ends of the bars are exposed, while the contact of the washers on the bars makes a water and steam tight joint.

2.



Thus the bar may be surrounded with ice, or, with steam, or, with a current of water of different temperatures, and be cooled or heated up to its terminal planes, while the holes in the washers allow the micrometer screws, M, M′, to be brought in contact with the terminal planes of the bar. Two helical springs are attached to the column, A. The other ends of these springs are fastened to rods projecting from the tube, T. Thus the same pressure of contact is always made between the bar and the end of the micrometer screw, M. The tube, T, is supported in Vs, V, V′, and the greater part of the weight of the tube is taken off the Vs by helical springs fastened to a frame above the apparatus. The tension of these springs can be so regulated that the tube rests on the Vs with the same pressure when the tube has steam passing through it or when it is filled with ice. The column, A, and the Vs, V, V′, are insulated from the base of the apparatus by thin plates of ebonite, *e*. Between the binding screws, E and E′, and connected by wires, are the voltaic cell, F, the galvanometer, G,

and a box of resistance coils, R. The micrometer-screw, M′, with which the variations in length of a bar are measured, is mounted as follows: The screw passes through its nut in a massive brass plate which rotates around nicely fitted centers at H. These centers are supported by two side plates not shown in the figure. A spring, K, is fastened to the lower part of the swinging nut-plate and brings this plate against the plate, L, firmly fastened to the base of the apparatus. When the swinging plate is vertical and the axis of the screw horizontal the swinging plate fits accurately the surface of the fixed plate, L. By turning the rod, N, the swinging plate and its screw can be rotated away from the bar. This arrangement allows the screw to be swung out of the way while the tube, T, is being placed in the Vs. Also, it prevents any strain between the micrometer-screw, M′, and the column, A; which would take place if M′ were fixed and it should be brought in contact with a hot bar in the tube, T.

With careful manipulation successive electric-contacts can be made on a bar in the tube, T, surrounded by ice, so that the variations in a series of measures will not exceed $\frac{1}{000}$ mm., with a resistance of about 200 ohms placed in the circuit.

It may be reasonably objected to this apparatus that when the micrometer-screw touches the bar at 0° it is cooled and shortened, and that when it touches the bar at 100°, or at temperatures higher than that of the screw, the latter is heated and elongated. This error, however, is quite small, and may be neglected in our work. If we assume that one centimeter of the screw is heated 10°, which is a large estimate, considering the duration of contact of screw and bar during a measure, the shortening or elongation of 1 cm. of the screw by cooling or heating it 10° amounts to only ·0012 mm., or $\frac{1}{10000}$ of the length of the bar. This change in the length of the screw will affect the coefficient of expansion of the bars only ·00000006.

Determination of the Densities of the Bars at 4°.

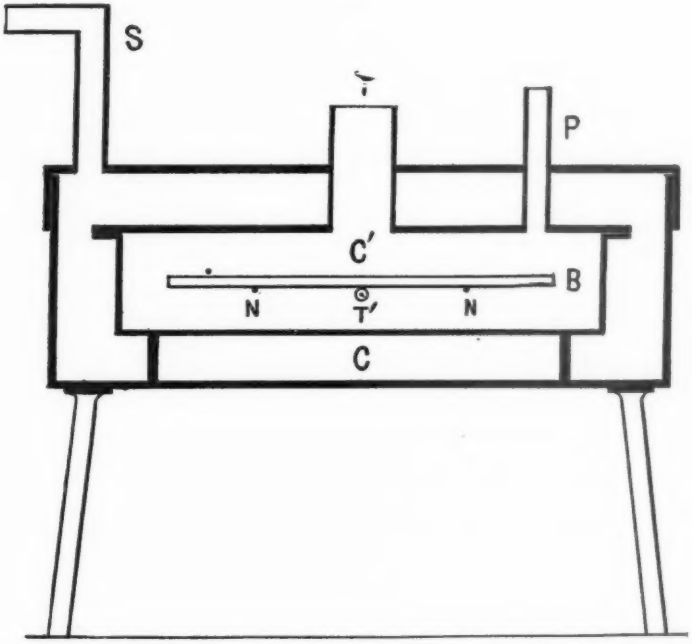
The bar, whose density was to be determined, was immersed in water at 4° for a couple of hours. The bar was then suspended by a platinum wire in water at 4° and weighed. The bar was then removed from the wire and a quantity of water equal in volume to the volume of the bar was added to the water in the vessel, and the platinum wire, now immersed exactly as it was when the bar was attached to it, was weighed. This weight, subtracted from the previous weighing, gave the weight of the bar in water. Every precaution was taken to prevent, by means of screens, the action on the balance of

the currents of cold air in the balance-case, which are produced by the constant descent of air from the sides of the cool vessel.

The Apparatus in which the bars were heated and cooled. On the precautions used so that one is sure of having the real temperature of the bar when it is vibrated.

The apparatus used to heat and cool the bar is shown in fig. 3. In a brass box, C, is inclosed a box, C′, containing the

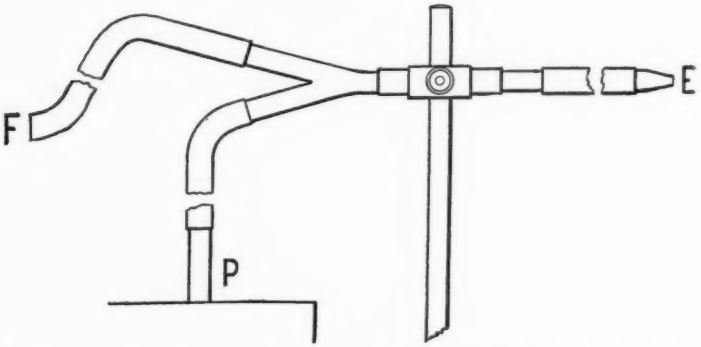
3.



bar, B, supported on its modes, N, N, by threads held by upright rods. From this central box two tubes, T, P, pass through the outer box C. The inner box is made water-tight and steam-tight by a rubber washer which is pressed between the top of the box and its cover by means of screws. Through the tube, T, the bar is vibrated by letting fall upon its center a rubber ball fastened to a light wooden rod. On the blow of the ball it rebounds and the rod is caught by the fingers in its upward motion. The cork is then at once replaced in the

tube, T. The sound from the bar is conveyed to the ear, at E, by means of a tube (fig. 4). One branch of this bifurcated tube leads through a rubber tube to the pipe, P, of the box, fig. 3. The other branch leads to the fork, F, the number of

4.



whose beats per second made with the vibrating bar is measured by a chronometer. The pipe, S, allows the steam to issue when water is boiled in the box, C′, by a gas lamp. The flow of gas through this lamp was neatly regulated by a stop-cock turned by a long lever. The box, C, is covered, except at the bottom, with thick felt.

To determine the frequencies of vibration of a bar through a range of temperature from 0° to 100°, the following method was used: The box, C, was filled with ice, surrounding the inner box, C′. It thus remained for an hour so that the boxes were cooled down to 0′, and the moisture in the inner box has been condensed so far as it can be at 0°. The bar, which has been in ice for two hours, is wiped dry and quickly introduced into the inner box. A thermometer, T (made by Baudin and corrected), entered the boxes through stuffing boxes, and whose bulb touched the under surface of the bar, was read till it became stationary. The bar was now vibrated and its frequency of vibration determined for the temperature given by the thermometer.

The lamp was now placed under the box and the water in it boiled till the thermometer reached its maximum reading and the reading remained stationary during a half-hour. The vibration frequency at this temperature was taken. The flame of the lamp was now lowered and the box allowed to cool very slowly, at the rate of 1° fall of temperature in about eight minutes. When the thermometer read 80°, 60°, 40°, the flame of the lamp was carefully adjusted, so that these successive tem-

peratures were maintained during 15 minutes. We then took the frequency of vibration of the bar.

The numbers of vibrations of the forks used in the determinations of the pitches of the bars were corrected for temperature by the coefficient ·0001118, determined by Dr. Kœnig in 1880 (Quelques Experiences d'Acoustique, Paris, 1882, p. 172, *et seq*).

The subsequent tables show the results of the experiments and give the computations of velocities and moduli founded on them. The curves express graphically the effect of change of temperature on the modulus of elasticity of all the bars experimented on. The circles, on or near the curves, give the data as determined by the experiments.

In Table III, T=temperature of bars, l=the length, t=the thickness, and V=the velocity of sound through the bars, in centimeters. M=the modulus in grams per square centimeter section of the bar. g, at Paris, equals 980·96. D=the density, and N=the number of vibrations of bar per second at temperature, T.

All of the bars were annealed, except those of Jonas and Colver steel, of the French aluminum and of brass; these were experimented on just as they came from the draw-bench.

For the analyses of the substances of the bars experimented on, I am indebted to my colleagues, Professors Stillman and Leeds.

TABLE I.

Bar.	l.	t.	V at 20°=	N computed by $N=V\,1{\cdot}0279\frac{t}{l^2}$	N observed at 20°.	Diff.
Steel No. 1 ..	20·022	·5025	150·02 × 3427·4 v. s.	662·49 v. d.	660·8	+1·69= $\frac{1}{391}$
" No. 2 ..	20·0246	·5037	=514178^{cms}	663·91 "	661·0	+2 91= $\frac{1}{227}$
" No. 3 ..	20·0225	·5022		662 07 "	660·3	+1·77=+ $\frac{1}{373}$
Aluminum.						
No. 1	20·0253	·4993	150·05 × 3377 v. s.	648·51 "	646·6	+1·91= $\frac{1}{338}$
No. 2	20 0296	·4991	=506719^{cms}	647·97 "	647·0	+0·97= $\frac{1}{667}$
No. 3	20·0233	·4998		649·80 "	648·0	+1·8 = $\frac{1}{360}$
Brass.						
No. 1	20·02	·50116	150·05 × 2386·4 v. s.	460·23 "	459·0	+1·23= $\frac{1}{373}$
No. 2	20·02	·50147	=358079^{cms}	460·53 "	458·95	+1·58= $\frac{1}{290}$
No. 3	20·02	·50108		460·16 "	458·35	+1·81= $\frac{1}{253}$
St. Gobain Glass	23·516	·747	152·2 × 3582 v. s. =538016^{cms}	747·03 "	749·75	−2·72= $\frac{1}{275}$
White Pine. Density=·365	41·15	·803	171·18 × 3072·75 v. s. =525993^{cms}	256·38 "	256·0	+0·38= $\frac{1}{673}$

Mean departure of computed from observed value = $\frac{1}{325}$ of observed value.

TABLE II.

Table of Analyses, of Densities at 4°, and of Coefficients of Expansion of Bars.

	Iron.	Carbon	Silicon	Phos.	Sulph.	Mang.	Nickel					
J. & C. Steel	98·259	1·286	0·015	0·059	0·031	0·350	----	Density @ 4°,		7·827,	coef't. expan.,	·0000110
No. 3 "	98·738	0·47	0·15	0·022	----	0·62	----	"	"	7·848,	"	·0000118
No. 4 "	98·628	0·51	0·158	0·024	----	0·68	----	"	"	7·845,	"	·0000120
No. 5 "	95·719	0·27	0·101	0·031	----	0·69	3·189	"	"	7.851,	"	·0000119
Bess'r. "	99·03	0·15	0·02	0·09	0·06	0·65	----	"	"	7·841,	"	·0000122

Brass.

Copper	64.34
Zinc	34 97
Lead	·58
Iron	·11
Density	8·476
Coeft. expan.	·0000185

Bell Metal.

Copper	80·08
Tin	18·97
Lead	·12
Zinc	·49
Density	8·347
Coeft. expan.	·0000187

Aluminum (Amer.).

Aluminum	98·99
Free Carbon (graphite)	·19
Combined Carbon	·16
Tin	·21
Silicon	·32
Iron	·15
Density	2·702
Coeft. expan.	·0000232

Aluminum (French).

Aluminum	97·80
Carbon with Si	·14
" free	·04
" with Copper	·09
Copper	1·29
Silicon	·64
Density	2·730
Coeft. expan.	·000022

Silver, Pure.

Density	10·512
Coeft. expan.	·0000184

Zinc.

Zinc	99·75
Iron	·10
Lead	·04
Density	6·8107
Coeft. expan.	·0000296

St. Gobain Glass.

Silicon	72·3
Alumina	·8
Lime	15·3
Soda	11·8
Density	2·545
Coeft. expan.	·00000777 (Fizeau.)

TABLE III.

Bar.	T.	l.	t.	$\frac{t}{l^2}$	D.	N.	$V=\frac{N}{1\cdot0279\frac{t}{l^2}}$	$M=\frac{V^2d}{g}$	M.
Jonas & Colver Cast Steel.	0·2	20·0207	·5036	·0012564	7·828	662·0	512602	2097585540	2097×10^6
	20	20·0246	·5037	·0012562	7·823	661·0	511908	2089805486	2090×10^6
	40	20·0286	·5038	·0012561	7·818	659·6	510112	2080863837	2081×10^6
	61	20·0328	·5039	·0012560	7·814	658·6	509389	2072936852	2073×10^6
	80	20·0366	·5040	·0012554	7·809	657·1	508470	2064153151	2064×10^6
	99·8	20·0406	·5041	·0012551	7·804	655·14	507065	2050537870	2050×10^6
Steel No. 3.	0	20·3513	·64049	·0015464	7·849	820·38	516124	2131430318	2131×10^6
	18·25	20·3558	·64063	·0015460	7·844	818·91	515329	2123515662	2123×10^6
	34	20·3594	·64074	·0015457	7·8395	817·50	514539	2115797406	2116×10^6
	60	20·3657	·64094	·0015453	7·832	814·70	512907	2100383667	2100×10^6
	80	20·3705	·64109	·0015449	7·8265	812·40	511586	2088031273	2088×10^6
	99·5	20·3752	·64124	·0015446	7·821	810·00	510175	2075047288	2075×10^6
Steel No. 4.	0	20·3517	·64295	·0015523	7·846	824·71	516238	2131556968	2135×10^6
	18·25	20·3562	·64312	·0015520	7·841	822·71	515708	2125826869	2126×10^6
	40	20·3614	·64328	·0015517	7·8345	821·25	514893	2117356581	2117×10^6
	51·5	20·3643	·64337	·0015514	7·831	819·67	514002	2109091886	2109×10^6
	81	20·3715	·64360	·0015508	7·823	816·30	512088	2091259452	2091×10^6
	97·6	20·3755	·64373	·0015505	7·819	814·00	510745	2079256951	2079×10^6
Steel No. 5.	0	20·3513	·64188	0015498	7·852	813·29	510527	2086250350	2086×10^6
	18·25	20·3559	·64202	·0015494	7·847	811·84	509757	2078637463	2078×10^6
	40	20·3609	·64218	·0015490	7·841	809·68	508529	2067052961	2067×10^6
	60	20·3657	·64233	·0015486	7·835	807·31	507168	2054430194	2054×10^6
	80	20·3706	·64248	·0015482	7·829	805·02	505856	2042249532	2042×10^6
	99·5	20·3753	·64264	·0015479	7·824	802·71	504506	2030066264	2030×10^6
Bessemer Steel	0·4	20·451	·60144	·0014380	7·8421	761·37	515093	2121057163	2121×10^6
	20	20·456	·60160	·0014377	7·8364	759·80	514032	2110783287	2111×10^6
	40	20·461	·60176	·0014374	7·8306	757·70	512960	2100440462	2100×10^6
	60	20·466	·60190	·0014370	7·8248	755·41	511409	2086216940	2086×10^6
	80	20·471	·60205	·0014367	7·8192	752·90	509710	2070893085	2071×10^6
	100	20·476	·60220	·0014363	7·8134	749·90	508026	2055702283	2056×10^6
Brass when bar was cooled from 99°·6 to 1°.	1°	22·0128	·5009	·0012506	8·4774	460·64	358337	1109672142	1109×10^6
	21·8	22·0208	·5011	·0012501	8·4677	458·95	357307	1102010322	1102×10^6
	40	22·0274	·50126	·0012497	8·4592	457·40	356103	1093479554	1093×10^6
	60	22·0348	·50144	·0012492	8·4498	455·70	355052	1085864045	1086×10^6
	80	22·0422	·50162	·0012488	8·4404	454·00	353727	1076578495	1076×10^6
	99·6	22·0494	·50180	·0012483	8·4312	452·30	352678	1069044150	1069×10^6
Brass before bar was heated to 99°·6.	0·4	20·0127	·5008	·0012504	8·4778	460·04	357928	1107191685	1107×10^6
	20	20·0208	·5011	·0012501	8·4685	458·35	356698	1098388907	1098×10^6
Bell Metal.	0	22·2402	·82054	·0016589	8·3490	572·05	335300	956864118	$956\cdot8\times10^6$
	21	22·2490	·82114	·0016588	8·3390	569·50	333806	947214927	$947\cdot2\times10^6$
	40	22·2568	·82168	·0016587	8·3302	567·12	332411	938324839	$938\cdot3\times10^6$
	50	22·2610	·82196	·0016587	8·3256	566·02	331766	934172231	$934\cdot2\times10^6$
	60	22·2650	·82224	·0016586	8·3208	564·94	331133	930074354	$930\cdot1\times10^6$
	74	22·2780	·82266	·0016586	8·3144	563·61	330354	924989117	$925\cdot0\times10^6$
	99·75	22·2818	·82338	·0016584	8·3025	561·21	328946	915914824	$915\cdot9\times10^6$

Bar.	T.	*l*.	*t*.	$\frac{t}{l^2}$	D.	N.	$V=\frac{N}{1{\cdot}0279\frac{t}{l^2}}$	$M=\frac{V^2d}{g}$	M
Aluminum (American).	0·4	21·612	·55176	·0011813	2·7027	621·00	511423	720621232	$720{\cdot}6\times10^6$
	20	21·622	·55200	·0011807	2·6990	618·10	509032	712929083	$712{\cdot}9\times10^6$
	45	21·6346	·55232	·0011800	2·6943	613·90	505993	703215278	$703{\cdot}2\times10^6$
	60	21·6422	·55250	·0011796	2·6915	611·60	504516	698390199	$698{\cdot}4\times10^6$
	82	21·654	·55278	·0011789	2·6874	607·88	501447	688868686	$688{\cdot}8\times10^6$
	99·5	21·662	·55300	·0011785	2·6840	604·71	499247	681974176	$681{\cdot}9\times10^6$
Aluminum (French).	0·5	20·0170	·49914	·0012457	2·7306	650·00	507632	717306505	$713{\cdot}0\times10^6$
	20	20·0253	·49930	·0012451	2·7270	646·60	505375	710002959	$710{\cdot}0\times10^6$
	40	20·0340	·49950	·0012445	2·7232	642·78	502388	700672761	$700{\cdot}6\times10^6$
	60·5	20·0428	·49965	·0012438	2·7194	639·19	499977	692975831	$692{\cdot}9\times10^6$
	81	20·0518	·49980	·0012430	2·7156	635·50	497477	685124447	$685{\cdot}1\times10^6$
	100	20·0600	·50000	·0012425	2·7120	632·00	494734	676700317	$676{\cdot}7\times10^6$
Silver.	0·3	17·2176	·4614	·0015564	10·5142	437·93	273736	803135399	$803{\cdot}1\times10^6$
	20	17·2250	·46158	·0015557	10·5022	437·35	273489	800762642	$800{\cdot}7\times10^6$
	30	17·2284	·46168	·0015554	10·4962	436·80	273201	798729900	$798{\cdot}7\times10^6$
	40	17·2316	·46176	·0015551	10·4960	435·80	272626	794797589	$794{\cdot}8\times10^6$
	60	17·2380	·46194	·0015545	10·4778	433·00	270979	783307979	$783{\cdot}3\times10^6$
Zinc.	0·3	18·2094	·44517	·0013426	6·8130	559·84	405663	1142925404	1143×10^6
	20	18·2200	·44534	·0013415	6·8010	557·84	404501	1134426237	1134×10^6
	40	18·2308	·44552	·0013405	6·7890	553·76	401844	1117556599	1117×10^6
	50·5	18·2364	·44560	·0013399	6·7826	551·22	400294	1107903320	1108×10^6
	62	18·2426	·44570	·0013390	6·7758	543·61	394291	1073843790	1074×10^6
St. Gobain Glass.	0·3	23·496	·74898	·0013566	2·5452	750·65	538313	751865836	$751{\cdot}8\times10^6$
	24·5	23 501	·74902	·0013562	2·5436	749·67	537769	749885431	$749{\cdot}8\times10^6$
	40	23·503	·74910	·0013561	2·5424	749·12	537403	788511034	$748{\cdot}5\times10^6$
	60	23·507	·74922	·0013558	2·5411	748·35	536909	746742620	$746{\cdot}7\times10^6$
	80	23·510	·74934	·0013557	2·5397	747·62	536497	745196510	$745{\cdot}2\times10^6$
	99·5	23·514	·74945	·0013554	2·5384	746·70	535955	743311215	$743{\cdot}3\times10^6$

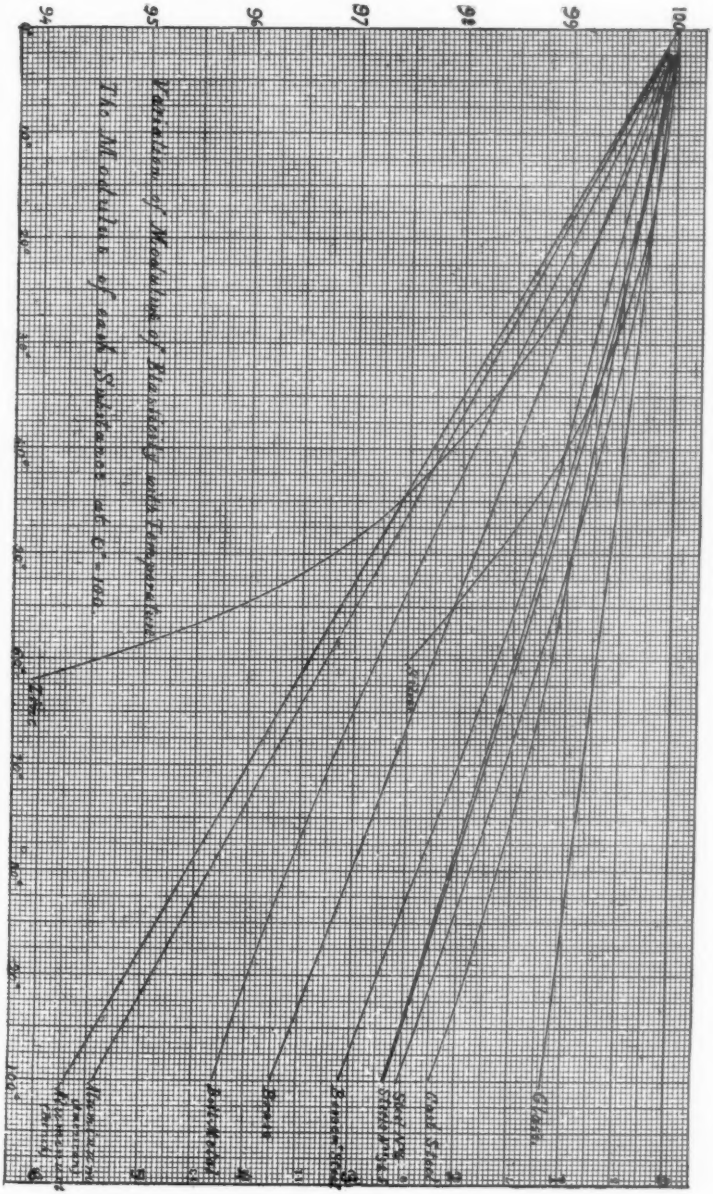
TABLE IV.

Variation of Modulus of Elasticity with change of Temperature.

In this table the modulus of each substance is taken as 100 at 0°. In computing this table the moduli taken were those obtained from the curves passing through the mean positions of the points determined by the experiments. The results contained in this table are expressed graphically in fig. 5.

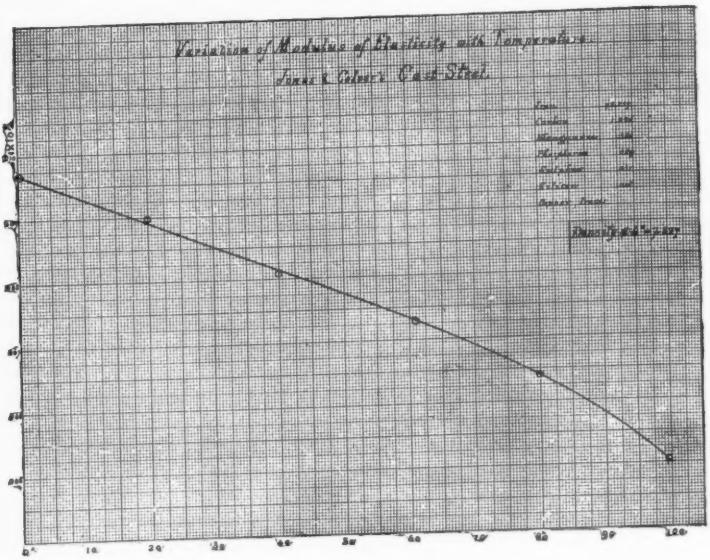
T.	J. & C. Steel.	Steel No. 3.	Steel No. 4.	Steel No. 5.	Bessemer Steel.	Brass.	Bell Metal.
0°	100·00	100·00	100·00	100·00	100·00	100·00	100·00
20°	99·61	99·57	99·70	99 58	99·53	99·26	99·03
40°	99·25	99·10	99·31	99·10	98·99	98·51	98·09
60°	98·87	98·58	98·8	99·54	98·35	97·76	97·21
80°	98·42	98·00	98·22	97·98	97·63	97·03	96·38
100°	97·76	97·34	97·54	97·35	96·91	96·27	95·70

	Aluminum (Amer.).	Aluminum (French).	Silver.	Zinc.	St. Gob. Glass.
0°	100·00	100·00	100·00	100·00	100·00
20°	98·92	98·86	99·73	99·26	99·88
40°	97·83	97·73	98·97	97·78	99·76
60°	96·75	96·58	97·53	93·96 (62°)	99·53
80°	95·67	95·42	----	----	99·30
100°	94·59	94·31	----	----	98·84

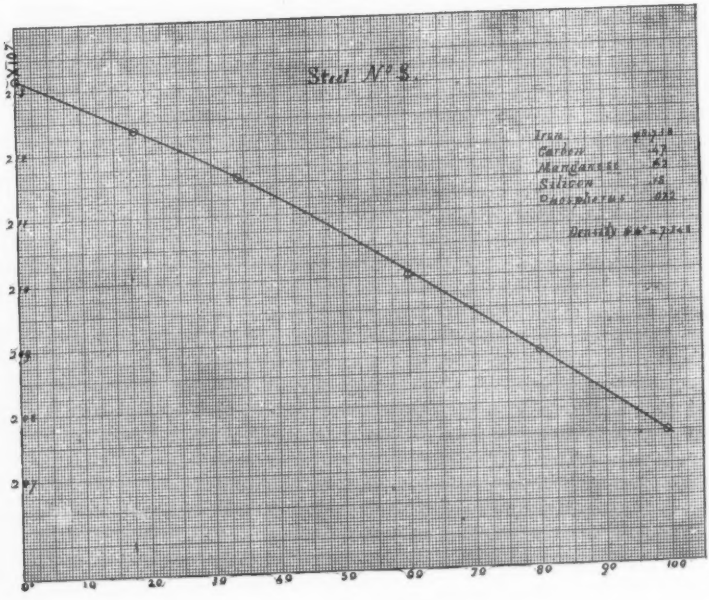

94
95
96
97
98
99
100
Variation of Modulus of Elasticity with Temperature
The Modulus of each Substance at 0° = 100.
Glass
Cast Steel
Steel Wire
Brass
Bell Metal
Magnesium
Aluminium
Platinum

5.

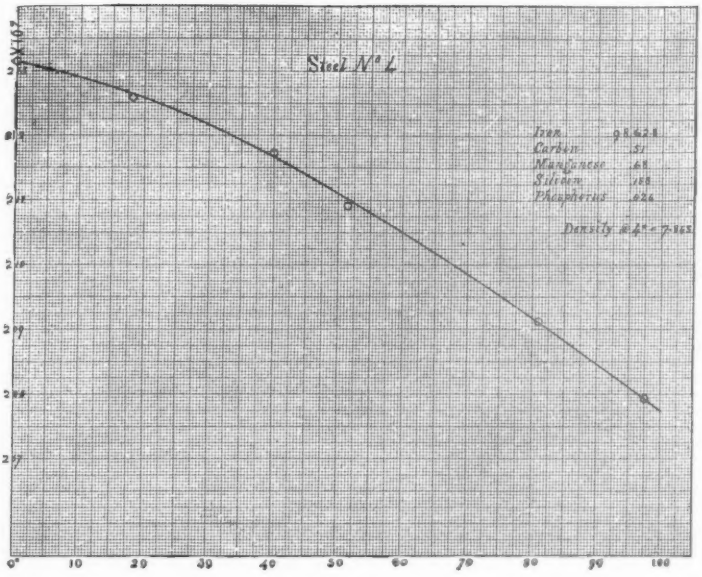
6.


Variation of Modulus of Elasticity with Temperature.
Jonas & Colver's Cast Steel.

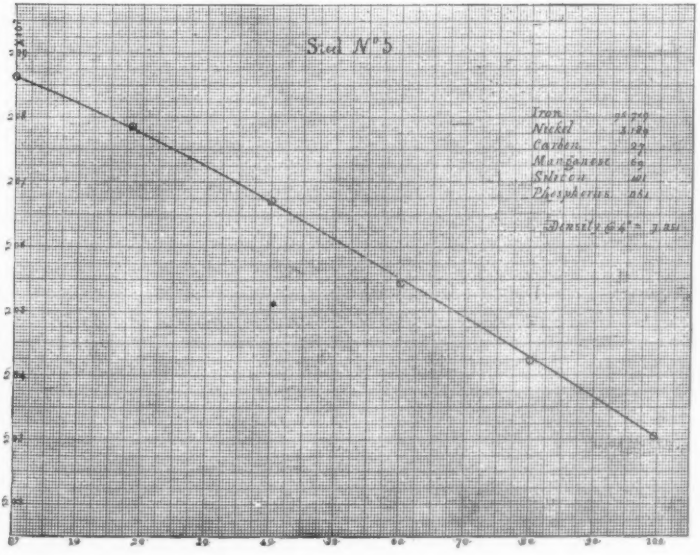
7.


Steel N° 8.

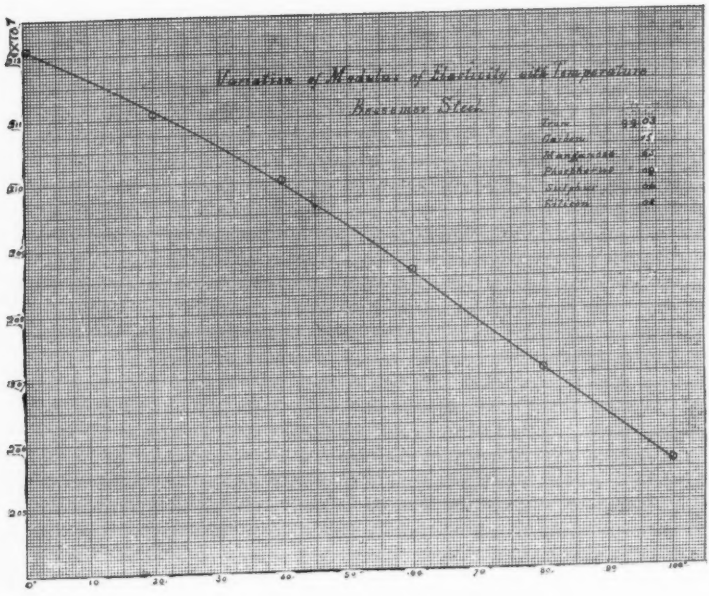
8.


Steel N° 4
Iron 98.628
Carbon .51
Manganese .68
Silicon .168
Phosphorus .026
Density @ 4° = 7.862
0° 10 20 30 40 50 60 70 80 90 100

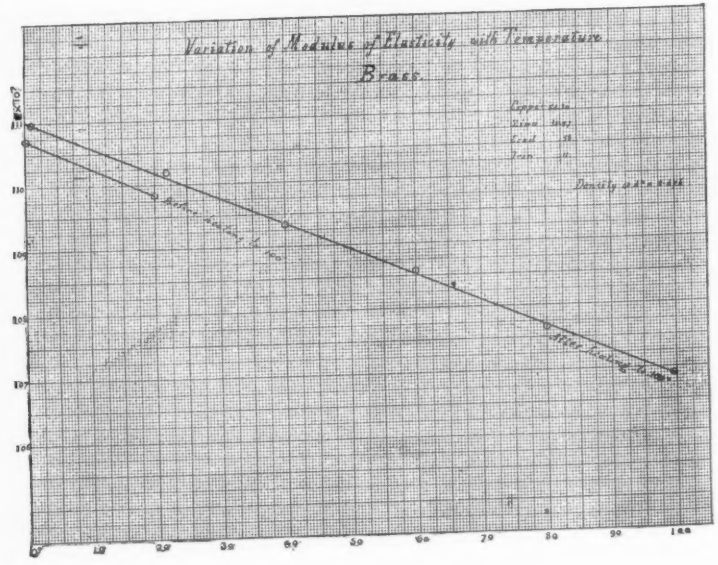
9.


Steel N° 5
Iron 96.709
Nickel 3.129
Carbon .97
Manganese .69
Silicon .401
Phosphorus .084
Density @ 4° = 7.851

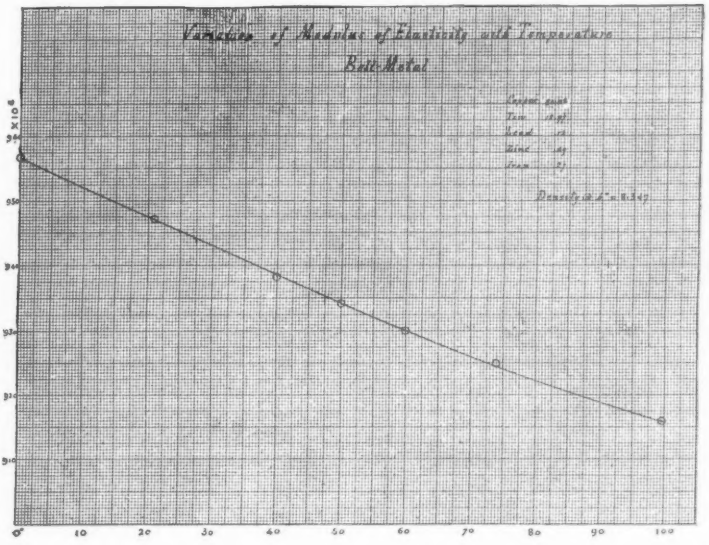
10.


Variation of Modulus of Elasticity with Temperature
Bessemer Steel.

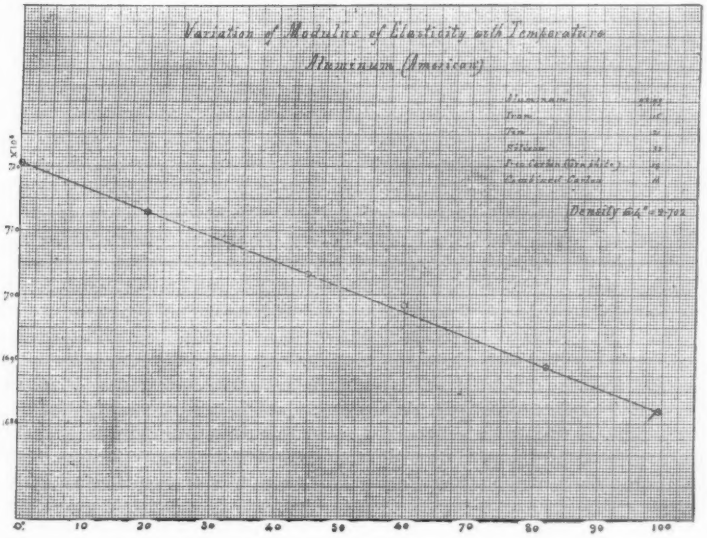
11.


Variation of Modulus of Elasticity with Temperature
Brass.

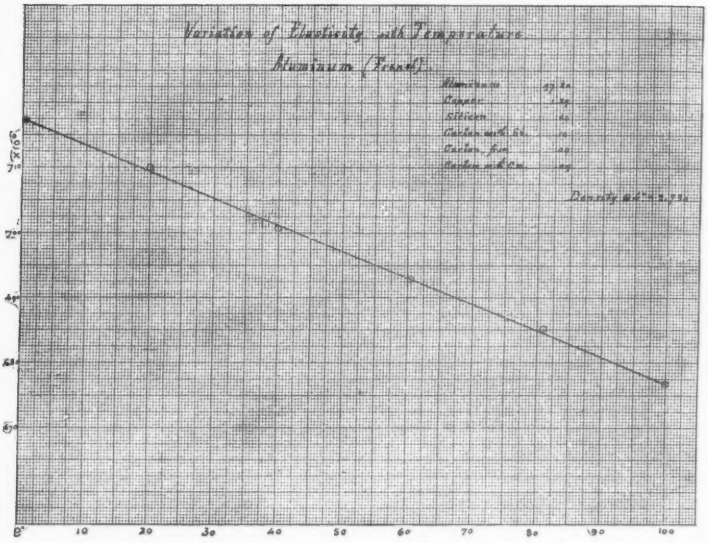
12.


Variation of Modulus of Elasticity with Temperature
Bell Metal
Density @ 0° = 8.147
0° 10 20 30 40 50 60 70 80 90 100

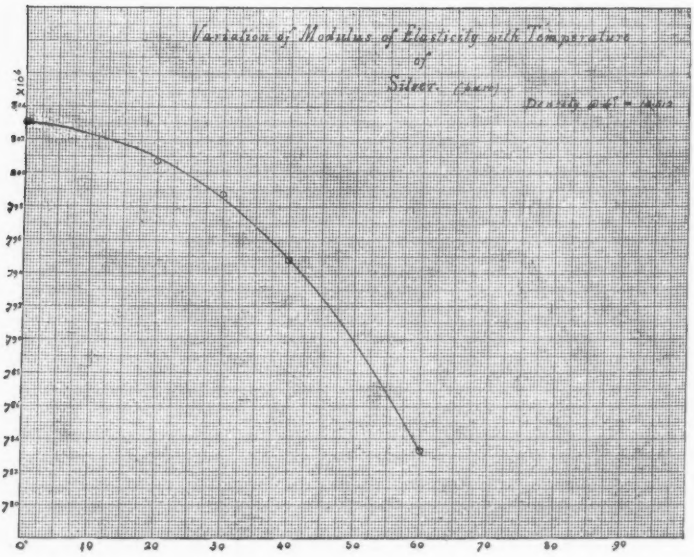
13.


Variation of Modulus of Elasticity with Temperature
Aluminum (American)
Density @ 0° = 2.702
0° 10 20 30 40 50 60 70 80 90 100

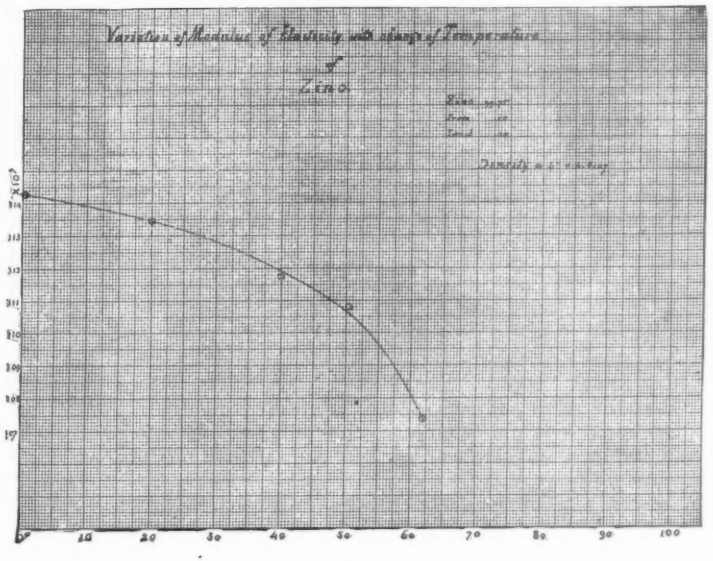
14.


Variation of Elasticity with Temperature
Aluminium (French).
Density at 0° = 2.732
0°
10
20
30
40
50
60
70
80
90
100

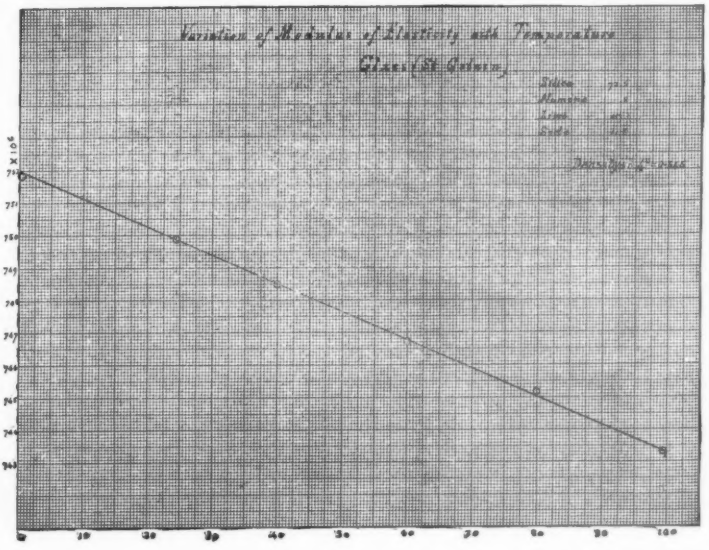
15.


Variation of Modulus of Elasticity with Temperature
of
Silver. (Hard)
0°
10
20
30
40
50
60
70
80
90

16.


Variation of Modulus of Elasticity with change of Temperature
of
Zinc.
Density
0
10
20
30
40
50
60
70
80
90
100

17.


Variation of Modulus of Elasticity with Temperature
Glass (Sil Quartz)
Density
0
10
30
40
50
60
70
80
90
100

Results obtained by other Experimenters on the change of the Modulus of Elasticity with change of Temperature.

I have found five researches on this subject. I here give abstracts of results from these papers.

Wertheim, 1844. Ann. de Chim. et de Phys.

IRON.

Modulus 5·2 per cent greater at 100° than at 18°.
Modulus 19·1 per cent less at 200° than at 100°.

IRON WIRE.

Modulus 4·9 per cent greater at + 10° than at −11°·6.
Modulus 7·42 per cent greater at 100° than at 18°.

WIRE OF ENGLISH CAST-STEEL.

Modulus 23·23 per cent greater at 100° than at 18°.
Modulus 9·46 per cent less at 200° than at 100°.
Modulus at 200° is 11·57 per cent higher than modulus at 18°.

STEEL WIRE TEMPERED TO BLUE.

Modulus 1·97 per cent higher at + 10° than at −10°.
Modulus 5·1 per cent higher at 100° than at 18°.

CAST-STEEL.

Modulus 2·8 per cent less at 100° than at 18°.
Modulus 5·73 per cent less at 200° than at 100°.

SILVER.

Modulus 5 per cent less at + 10° than at −13°·8.
Modulus 1·87 per cent greater at 100° than at 18°.
Modulus 12·87 per cent less at 200° than at 100°.

COPPER.

Modulus 6·53 per cent less at + 10° than at −15°.
Modulus 6·58 per cent less at 100° than at 18°.
Modulus 20· per cent less at 200° than at 100°.

WIRE OF BERLIN BRASS (Cu.=67·55 . Zn.=32·35).

Modulus 7·95 per cent less at + 11° than at −10°.

Kupffer, 1856. Mem. de l'Acad. de St. Petersb.

Modulus of iron wire 5·5 per cent less at 100° than at 0°.
Modulus of copper wire 8·2 per cent less at 100° than at 0°.
Modulus of brass wire 3·9 per cent less at 100° than at 0°.

Kohlrausch and Loomis, 1870. Pogg. Ann.

Modulus of iron wire 5 per cent less at 100° than at 0°.
Modulus of copper 6 per cent less at 100° than at 0°.
Brass 6·2 per cent less at 100° than at 0°.

H. Tomlinson, 1887. Phil. Mag.

Says, "my own experiments show that both the torsional and longitudinal elasticities are decreased about $2\frac{1}{2}$ per cent when the temperature of steel is raised from 0° to 100°."

M. C. Noyes, 1895. The Physical Review.

Modulus of a piano wire of $\frac{4}{10}^{mm}$ diam. 5 per cent less at 100° than at 0°.

The results of Wertheim's experiments giving an increase to the modulus, as the temperature rises, of iron, iron wire, wire of English cast-steel, steel wire drawn to blue and silver, have not been confirmed in any instance by subsequent experiments; only for cast-steel *rod* and copper did he obtain a diminution of modulus for a rise of temperature from 18° to 100°. Yet, he found that a *wire* of English cast-steel had a modulus 23 per cent higher at 100° than at 18°.

On the Acoustical Properties of Aluminum.

The low density (2·7) of aluminum combined with a modulus of elasticity of only 712×10^6 renders this metal easy to set in vibration; a transverse blow given to a bar of this metal causes it to vibrate with an amplitude of vibration greater than that which the same energy of blow would have given to a similar bar of steel or of brass. This fact has given rise to the popular opinion that aluminum has sonorous properties greatly exceeding those of any other metal. This opinion is erroneous. If a bar of aluminum and a bar of brass having the same length and breadth and giving the same note, are struck transversely so that the bars have the same amplitude of vibration, the bars give equal intensity of sounds; but the bar of aluminum from its low density and because of its internal friction will vibrate less than one-third as long as the bar of brass. Thus, a bar of aluminum and a bar of brass of the same length and width and of such thickness that they gave the same note, SOL_4 of 768 v. d., were vibrated so that the sounds at the moment of the blows were, as near as could be judged, of the same intensity. The duration of the sound of the brass bar lasted 100 seconds; the sound of the aluminum bar lasted 30 seconds.

The readiness with which a bar of aluminum vibrates when acted on by aerial vibrations of the same frequency as those

given by the bar, gives one the means of making many charming experiments in which "sympathetic vibrations" come into play.

I here describe an experiment which I devised to show the interference of sound in a manner similar to analogous experiments in the case of light. The resonant box on which Koenig mounts his UT_5 (1024 v. d.) fork is open at both ends and has a length of nearly a half wave of the sound of the fork. If this resonant box is held with its axis vertical, above an aluminum bar in tune with the vibrating fork, the bar does not enter into sympathetic vibration with the fork, because the sonorous pulses, on reaching the aluminum bar from the two openings of the resonant box, differ in phase by one-half wave-length. But if the axis of the box is held parallel to the axis of the bar, then the sonorous waves reaching the bar have travelled over equal lengths from the openings at the ends of the box, and these waves conspire in their action and the aluminum bar enters into sympathetic vibration.

As this experiment is an interesting one, I here give details as to the manner of making it. The bar of aluminum has a large surface, having a length of 17^{cms} and a width of 5^{cms}. The two nodal lines, which are distant from the ends of the bar equal to $\frac{2}{9}$ths of its length, are drawn on the bar. The bar is supported under these nodal lines on threads stretched on a frame. This frame is of such a height that the under surface of the aluminum bar is $8{\cdot}4^{cms}$, or one-quarter wave length, above the surface of the table, so that the vibrations of the bar and those of the waves reflected from the table will act together. The upper surface of the bar is covered with a piece of thick cardboard, in which is cut a rectangular aperture, having for length the distance between the nodal lines and a width equal to that of the bar. As this piece of cardboard rest on supports which lift it a slight distance above the surface of the bar, the latter, when it vibrates, does not send to the ear the vibrations of the surfaces of the bar included between its nodal lines and its ends, and which vibrations are opposed in phase to those given by the central area of the bar. Thus the sound emitted by the bar is much increased and the experiment rendered more delicate and improved in every way. I have found that the experiment succeeds best when the center of the resonant box is held about 58^{cms}, or, $7\frac{\lambda}{4}$ above the surface of the aluminum bar. This experiment works best in the open air, away from the action of sound-waves reflected from the walls and ceiling of a room.

The fact that aluminum gives, from a comparatively slight blow, a great initial vibration and that its vibrations last for a short time, render this metal peculiarly well suited for the construction of those musical instruments formed of bars which are sounded by percussion and the duration of whose sounds is not desirable.

I had hopes that the aluminum would prove to be a good substance out of which to make plates on which to form the acoustic figures of Chladni. Experiments have shown that aluminum is not suited to this purpose. I had plates of aluminum carefully cast, with 2^{cms} of thickness. These plates were turned down on the face-plate of a lathe to thicknesses of 2^{mm} and $3{\cdot}8^{mm}$. Three of these plates were quite homogeneous in elasticity, for the Chladni figures when obtained on them were symmetrical. Yet the Chladni figures were difficult to produce, because it is difficult to obtain a pure tone from an aluminum plate. The sound is generally more or less composite; therefore, the plate in its vibration tends to form two or more figures at the same time, and the consequence is that either no figure is formed or one is given that is not sharply defined. One square plate of $30{\cdot}8^{cms}$ on the side and $\cdot38^{cm}$ thick, gave quite clearly the three following tones: UT_2 (1), SOL_2 (2), and SOL_4 (3). Corresponding respectively to the Chladni figures of (1) two lines drawn from opposite points of the center of sides of plate; (2) figure formed of the two diagonals drawn from the corners of plate; (3) figure similar to (1) but with corners of plate cut off by curved lines. Fig. 4 corresponded so nearly to the sound of SOL_4 that a vibrating SOL_4 fork when held near the plate set the latter into vigorous vibration.

Another difficulty met with in using plates of aluminum for Chladni's figures is that sand, even when entirely free of salt and of the globular grains of wind-blown sand, does not move freely over a vibrating surface of aluminum, whether this surface has been polished or has been slightly tarnished and roughened by the action of alkali.

There is one serious objection to the use of aluminum in the construction of musical and acoustical instruments, and that is the great effect that the change of temperature has upon its elasticity. If a bar of aluminum and a bar of cast-steel be tuned at a certain temperature to exact unison, a change from that temperature will affect the frequency of vibration of the aluminum bar $2\frac{1}{2}$ times as much as the same change of temperature will affect the bar of cast-steel.

ART. XII.—*On the Improbability of Finding Isolated Shoals in the Open Sea by Sailing Over the Geographical Positions in which they are Charted;* by G. W. LITTLEHALES, U. S. Hydrographic Office.

MANY of the isolated shoals that are represented on nautical charts of the oceans have been located from the reports of mariners who have discovered them incidentally in making voyages of commerce. Previous to the year 1860, when there was no exact knowledge of the depths of the oceans, the vague reports of navigators, often doubtless based upon the observation of floating objects and of misleading appearances of the surface of the sea, caused the charting of many dangers for the existence of which there is no substantial foundation. But, as our knowledge of bathymetry increased, the existence of many of them was disproved, and they were removed from the charts.

As a result of these experiences, there arose a traditional distrust among mariners and hydrographers of the existence of many of these dangers that still appear on the charts with well founded evidence, and there is perhaps a disposition on the part of many to claim that they should be removed upon scant evidence of their non-existence. It is not uncommon for a mariner to report that, being in the vicinity of a charted rock or shoal, he laid his course so as to pass over the geographical position assigned to it with one hundred fathoms of line out or with lookouts posted aloft, but was unable to detect any evidence of its existence, and that he does not believe, therefore, that the rock or shoal exists. It seems necessary, therefore, to inquire into the degree of confidence that can be placed in such a piece of evidence of the non-existence of a danger, and to establish what probability there would be of finding it under these conditions.

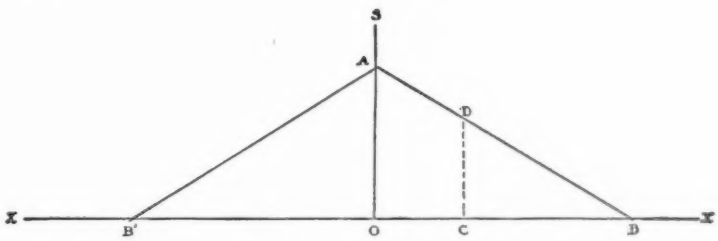
Suppose that A discovers, in the open ocean, a shoal r miles in radius, and determines the geographical position of its center subject to extreme errors of m miles in longitude and n miles in latitude; and that B, who is able to establish his geographical position within the same limits of extreme error as A, attempts to find the shoal again by proceeding to the geographical position assigned to it by A. What is the probability that he will find it?

If A, after making the discovery, had revisited the shoal a great number of times and had deduced the latitude and longitude of the same spot, under the same circumstances, at each visit, the latitudes would all differ from the true latitude and,

likewise, the longitude from the true longitude. If we call the differences between the true latitude and each deduced latitude errors of latitude and lay them off, according to their signs, to the right and left of an assumed origin, and then, corresponding to each error as an abscissa, erect an ordinate of a length proportional to the probability of that error, these ordinates and abscissas will be the coördinates of the probability curve. And, likewise, if the errors in longitude were found and plotted in conjunction with their probabilities, a similar curve would be developed.

In this investigation the probability curve, ordinarily represented by Laplace's formula, $y = ce^{-a^2t^2}$ will be replaced by two equally inclined straight lines AB and AB′ as shown in figure 1.

1.



This substitution, which has been employed by Hèlie in his Traitè de Balistique Expèrimentale and referred to by Wright in his work on the Adjustment of Observations, causes an appreciable but extremely small error which has no practical significance when we consider that, from the nature of the calculations about to be made, absolute precision is not to be sought.

The probability of having an error between $Oc = x$ (figure 1) and $x + \Delta x$, to the right of the axis OS, is equal to $s \,.\, dx$. As, in this case, OB and OB′ measure the extreme errors, all possible errors are comprised between zero and OB, and zero and OB′; and the sum of all the elements which are singly represented by $s \,.\, dx$, or the area of the triangle ABB′, should be equal to unity, which is the measure of certainty. The equation to the straight line AB will be, calling m the extreme error OB and b the intercept on the axis of S,

$$\frac{s}{b} + \frac{x}{m} = 1$$

but, since the area $ABB' = b \times m = 1$ or $b = \frac{1}{m}$ this equation becomes

$$sm + \frac{x}{m} = 1$$

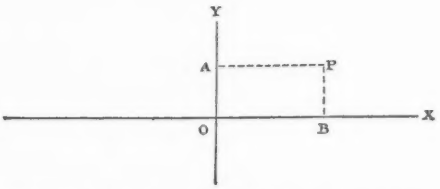
or
$$s = \frac{m-x}{m^2}$$

And since x can only vary between zero and m, the probability of having an error between x and $x+\Delta x$

$$p_1 = \frac{m-x}{m^2} \cdot dx \qquad (1)$$

The causes which produce the grouping of a number of deduced geographical positions around the true one are of two kinds; one tending to place the deduced latitude to the north or south of the true latitude, and the other tending to place the deduced longitude to the east or west of the true longitude. So that a particular deduced geographical position P will be the result of having an error OA in latitude and an error OB in longitude.

2.



The probability that the geographical position deduced by A, upon his discovery of the shoal, occupies a certain position with reference to the true geographical position of the shoal is, therefore, easily deduced. Through the true geographical position of the shoal let two rectangular axes, OX and OY, be passed as shown in figure 2. Upon the former conceive errors in longitude to be measured, and upon the latter, errors in latitude. The position P, of which the coördinates are x and y, results from the concurrence of two conditions, the error of x miles in longitude and the error of y miles in latitude. The probability p_1 of the error x is, as shown by equation (1),

$$p_1 = \frac{m-x}{m^2} \cdot dx$$

and, in the same manner, the probability p_2 of the error y will be

$$p_2 = \frac{n-y}{n^2}\, dy \qquad (2)$$

In these formulas, m and n represent respectively the extreme errors in longitude and latitude in miles.

The probability p of having, at the same time, the error x and the error y, or of deducing the geographical position P as the position of the shoal, will be the product p_1, p_2, or

$$p = \frac{(m-x)\ (n-y)}{m^2n^2}\ dx\,.\,dy \qquad (3)$$

an equation in which x can vary from zero to m, and y from zero to n. It is, therefore, applicable to the first right angle of the axes OX and OY, but, in order to make it applicable to other quadrants, it is only necessary to change the signs of x and y.

Equation 3 then expresses the probability that A's determination of the geographical position of the shoal is in error by x miles in longitude and y miles in latitude.

If the center of the shoal were really located in the geographical position assigned to it by A, and B should succeed in coming within r miles of it, he would find the shoal since its radius is r miles.

We have, therefore, as the second step in the solution of the problem, to determine what is the probability that B will come within a circular area, r miles in radius, having its center anywhere within the rectangle described about the true position of the shoal with sides equal to the extreme errors to which the determinations of latitude and longitude by A and B are subject.

To find the probability, P, of coming within any portion of the rectangle of extreme errors inclosed by a curve whose equation is $y = f(x)$, it is sufficient to integrate the expression (3) between limits depending only upon $y = f(x)$, and we shall have, in the first right angle,

$$\mathrm{P} = \frac{1}{m^2n^2}\int dx \int (m-x)\ (n-y)\ dy \qquad (4)$$

For a circular area of radius r, we shall have for the first quadrant,

$$\mathrm{P} = \frac{1}{m^2n^2}\int_0^r (m-x)\ dx \int_0^{\sqrt{r^2-x^2}} (n-y)\ dy$$

and for the whole circle,

$$\mathrm{P} = \frac{4}{m^2n^2}\int_0^r (m-x)\ dx \int_0^{\sqrt{r^2-x^2}} (n-y)\ dy$$

or

$$\mathrm{P} = \frac{2r^2}{mn}\left\{\frac{\pi}{2} - \frac{2r}{3m} - \frac{2r}{3n} + \frac{r^2}{4mn}\right\} \qquad (5)$$

The probability that B will find the shoal depends upon the concurrence of two independent conditions whose separate

probabilities are represented by equations (3) and (5) respectively, and is, therefore, equal to P . p, or

$$\frac{2r^2}{mn}\left\{\frac{\pi}{2}-\frac{2r}{3m}-\frac{2r}{3n}+\frac{r^2}{4mn}\right\}\frac{(m-x)\,(n-y)}{m^2n^2}\,.\,dx\,.\,dy \qquad (6)$$

Integrating the two expressions which make up equation (3) between the limits x and $x+\Delta x$ and y and $y+\Delta y$, respectively, the above expression becomes:

$$\frac{2r^2}{mn}\left\{\frac{\pi}{2}-\frac{2r}{3m}-\frac{2r}{3n}+\frac{r^2}{4mn}\right\}\frac{\Delta x}{m}\left(1-\frac{2x+\Delta x}{2m}\right)\frac{\Delta y}{n}\left(1-\frac{2y+\Delta y}{2n}\right),$$

which, for $r=1$ mile, $x=2$ miles, $y=2$ miles, $m=10$ miles, $n=10$ miles, and Δn and Δy each equal to 1 mile, becomes $\frac{1}{6173}$. That is, under the conditions stated, B would stand one chance in 6173 of finding the shoal.

Art. XIII.—*Notes on Sperrylite;* by T. L. Walker.

The interesting mineral sperrylite was first described by Professors Penfield and Wells in 1889.* Being a diarsenide of platinum and crystallizing in pyritohedral forms, it serves to link the platinum group of metals with the iron group, since in the latter group diarsenides and disulphides commonly crystallize in pyritohedral forms. In June, 1893, the writer obtained permission from Mr. H. P. McIntosh, secretary of the Canadian Copper Company, to visit the Vermillion mine in Algoma, Ontario, and to obtain specimens of sperrylite and associated minerals. The notes here submitted are derived from an examination of the material collected.

Professor Penfield described four crystal forms on sperrylite, (111), (001), (110) and π(210), but he also adds: "Some crystals appear to be somewhat rounded by other faces, but none of the latter could be determined."†

Some of the larger and more promising crystals were examined under the microscope. The common forms observed were (111) and (001), generally in combinations in which the former usually predominates. The form (110) was not recognized on any of the crystals examined. π(210) could be seen on most of the larger crystals, though the faces were generally small. Another form was observed which replaces the angles formed by (111), (001), and π(210). The edges formed by the intersection of these new faces with π(210) are parallel, and hence the new form belongs to the same zone as π(210). The

* This Journal, xxxvii, 67, 71, 1889; Zeitschr. f. Kryst., xv, 285 and 290.
† Zeitschr. f. Kryst., xv, 291.

edges formed by the intersection of the cubic faces with the octahedral faces and with the new faces, form on the cubic faces plane angles which gave the following measurements:

155° 35′	156° 15′
155° 55′	156° 20′
156° 10′	156° 50′

Average measurement, 156° 9′.
Calculated for $\pi(10{\cdot}5{\cdot}2)$ 156° 49′.

The calculated symbol for these new faces agrees very closely with the di-dodecahedron $\pi(10{\cdot}5{\cdot}2)$, which has not been previously determined for sperrylite; $\pi(11{\cdot}5{\cdot}2)$ occurs on pyrite and is very close to the faces here described. There are still other faces present on some of the crystals, but they are too small to be determined on the present material.

Small crystals are frequently observed, half-imbedded in the cubic faces of the larger ones. These guest crystals appear to possess the same orientation as the host, and generally show combinations of (001) and (111). The hemihedral faces may occur on the smaller individuals, but could not be determined. In intergrowths of pyrite, the pyritohedral faces are so disposed that the whole is regarded as interpenetration twins with the twinning axis normal to (110). This is well seen in the so-called "iron cross." That the crystals of sperrylite follow the same law of twinning is highly probable, but we cannot regard it as proved from the present observations. The detection of pyritohedra or di-dodecahedra on the guest crystals and the determination of their position with regard to that of the corresponding faces on the larger crystal, would settle the question beyond dispute.

Sperrylite occurs in loose decomposition products of chalcopyrite, pyrrhotite and other iron-nickel sulphides. The concentrates obtained by "panning" consisted principally of grains of chalcopyrite and pyrrhotite along with crystals of magnetite, sperrylite, and cassiterite. The chalcopyrite grains showed on closer examination that they frequently contain crystals of sperrylite. The fragments of pyrrhotite were carefully examined, but in no case could crystals of sperrylite be observed on them. The chalcopyrite is therefore the original host of the sperrylite. In this connection it may be mentioned that in all the copper-nickel mines of the Sudbury district, traces of the metals of the platinum group are found, and also that nickel matte from mines low in copper contains very little nickel, while mines richer in copper afford a matte proportionally richer in platinum. In short, the platinum contents of nickel matte in the Sudbury district is directly proportional to the copper contents, viz: proportional to the amount of copper pyrites in the original ore. This fact, taken

in connection with the detection of sperrylite in fragments of chalcopyrite, while a careful search did not reveal it in the pyrrhotite fragments, renders it very probable that the platinum found in the Sudbury district, in the copper-nickel mines, in general occurs as sperrylite and that this mineral occurs generally if not exclusively in chalcopyrite. It should be mentioned here, however, that according to some analyses,* polydymite, which occurs very sparingly in some of the Sudbury mines, contains from 0·006 per cent to 0·024 per cent platinum. Sperrylite dissolves slowly in strong hot hydrochloric acid, more readily in aqua regia, while in nitric, sulphuric and hydrofluoric acids it is practically insoluble.

An analysis of Manhée matte from Murray mines gave the following results:

Nickel (with trace cobalt)	48·82%
Copper	25·92
Iron	2·94
Sulphur	22·50
Gold	·000075
Silver	·001775
Platinum	·000430
Iridium	·000056
Osmium	·000057
Rhodium	small quantity
Palladium	small quantity
Total	100·182393%

In this as in similar analyses made by others the presence of iridium and osmium is noted. In Professor Wells's analyses† of sperrylite these metals are not detected, though he was at special pains in searching for iridium. Baron H. B. von Foullon‡ concludes, from the presence of these metals in the Sudbury ores, that there is another mineral present which contains the iridium. This is possible, but more probably in some cases part of the platinum in sperrylite is replaced by the elements iridium and osmium. This would not appear to be the case, however, in the Vermillion mine sperrylite as shown by Professor Wells's analyses.

The above observations were carried on in the laboratories of the School of Mines at Kingston, Ontario, and at the Mineral Institute at Leipzig. For advice and assistance I am especially indebted to Dr. W. L. Goodwin and Professor Nicol of Kingston and also to Herrn Geheimrath Professor Zirkel of Leipzig.

Leipzig, Saxony, November, 1895.

* Bull. U. S. Geol. Survey, No. 64, p. 21.
† This Journal, 1889.
‡ Jahrb. d k. k. geol. Reichsanstalt, 1892, p. 301.

ART. XIV.—*Note on the Glaciation of Pocono Knob and Mounts Ararat and Sugar Loaf, Pennsylvania;* by HENRY B. KÜMMEL, PH.D.

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DURING the past field-season an opportunity was given me, in connection with my work on the glacial deposits of Northern New Jersey, to visit Pocono Knob, Monroe County, and Mounts Ararat and Sugar Loaf, Wayne County, Pennsylvania. The Pennsylvania State geologists* have held that during the glacial period these peaks were nunataks.

Pocono Knob is an outlier of Pocono Plateau, situated about nine miles northwest of Stroudsburg. The terminal moraine is well developed on its north and south flanks, about two-thirds of the way up the slope. Since this knob was examined by Lewis and Wright, a wagon road has been constructed up the northwest side and along the top of the hill for more than half a mile. This road affords almost continuous exposures to a depth of from one to three feet, along the top of the knob. Here was found a considerable variety of material, chiefly shales and sandstones of different color, texture, and lithological constitution, with some coarse conglomerate. Not a few of these had been worn to subangular form with more or less well marked planation surfaces. Fragments bearing striæ, of whose origin there can be no doubt, are not abundant, but ten or twelve cobbles were found, which bore unmistakable glacial scratches. Some of these occurred not more than thirty feet below the summit. The evidence is conclusive that the ice covered the western part of the hill to within at least thirty feet of the highest point. That it also covered the crest is very probable.

When one leaves the road and examines the weathered material on the surface, hidden, as it is, by vegetation, it is next to impossible to convince oneself, that there is any glacial debris on the knob, and during the earlier part of my investigation, before I had examined the exposures along the road, I held the same opinion as those who had earlier studied the ground.

On the highest point of the hill, the surface is strewn with large bowlders of disintegration, and the ledges show no signs of glacial action. No evidence of glaciation could be found on that part of the hill which lies east of the summit, where there are no exposures, but in view of what was found along the road, where the opportunity for observation is good, there can

* Lewis, Second Geological Survey of Pennsylvania, Terminal Moraine, Z, pp. 75, 271. White, idem., Susquehanna and Wayne, G5, pp. 25, 159.

hardly be any doubt but that the whole knob was covered by the ice. The amount of material left by it was, however, small.

North of Dry Gap, as the col connecting the knob with the plateau is called, the characteristic topography of the terminal moraine is strongly developed. Fresh cuts along the recently constructed line of the Wilkesbarre and Eastern railroad give fine exposures of the glacial deposits. Since the data now at hand prove that the ice covered the knob, the connection between these two parts of the moraine is probably through Dry Gap,* but the typical morainic topography is not developed at that point.

Sugar Loaf and Ararat, in the northwestern part of the State, are 2475 and 2650 feet high,† respectively, and rise about 500 and 700 feet above the general level of the surrounding plateau. Both are thickly covered with underbrush and timber, and exposures are almost entirely wanting. On the north face of Sugar Loaf, glacial material was found along an old wood road, two-thirds of the way up (as far as the road extended). Above that height nothing definite could be made out for lack of exposures. The surface, however, was not radically unlike that of the lower part of the hill. The few rock ledges which occur do not bear striæ, nor have they roche moutonnée surfaces. However, ledges of sandstone so exposed to the weather could hardly be expected long to retain glacial markings.

On Ararat the facts are much the same. From want of opportunity for critical examination I was unable to prove that the ice covered the highest points, nor was I able to satisfy myself that it did not.

Although in the present state of things, it is impossible to obtain conclusive data, there are certain considerations which indicate that the excepted view is probably not the correct one. At the Delaware Water Gap, the ice filled the gorge and overrode, with very little deflection, the crest of Kittatinny mountain, which rises 1300 feet above the river and 600 to 700 feet above the general level of Kittatinny valley. If the ice was of sufficient thickness to accomplish this at points less than seven miles from its margin, it seems improbable that the ice-sheet was not thick enough to override hills such as Ararat and Sugar Loaf, which rise less than 700 feet above the surrounding plateau, and which are seventy miles north of the margin of the ice. There can be no doubt but that, were the crests of these hills cleared and excavations made, traces of glacial drift would be found here as at Pocono Knob.

Geological Survey of New Jersey,
Trenton, N. J.

* This was suggested by Lewis in a supplementary note to his report (l. c., p. 271), although in the report he had mapped the moraine as extending around the eastern end of the knob.

† White, l. c., p. 17.

ART. XV.—*The Counter-twisted Curl Aneroid;** by CARL BARUS, Hazard Professor of Physics at Brown University.

INTRODUCTORY.

1.—IT seems plausible to argue that much goes on in the atmosphere immediately related to pressure which the ordinary pneumatic barometer merely integrates, and of which it can give no detailed account. I refer both to the changes referable to the gusty character of the wind † and to pressure variations of a more subtle nature,‡ the origin of which may be considered in relation to the earth's magnetic and electrical field.

2.—The problems, therefore, are beyond the immediate scope of instruments of large mass like the ordinary mercury or water barometers. The conditions to be fulfilled are (1) great sensitiveness and (2) instantaneous indications; (3) registry subject to corrections of a purely scientific kind. It is when these three conditions are simultaneously demanded that the problem becomes formidably difficult. No matter what form of mechanism is selected, one is brought face to face at once with viscosity and with the thermal variations of both viscosity and of elasticity.

I desire in this paper to find out how far one can go with suitable modifications of the Bourdon tube. In certain measurements§ of high pressure made with such a tube coiled helically I received much encouragement, inasmuch as the instrument could be read off closely enough, without the aid of subsidiary mechanism. The difficulties which I then encountered were purely technical. In flattening and coiling the necessarily heavy tube, I had to remove the temper at a sacrifice of strength and resilience, and the gauge actually burst at 1000 atmospheres. I abandoned it simply because of the difficulty in fashioning this cumbersome apparatus in the laboratory.

In relation to low pressures, however, all of these difficulties fall away at once, and it becomes merely a question of patience to find the limit of constancy and precision to which a gauge of this kind can be pushed.

The conditions of sensitiveness were discussed not long ago

* The present research was encouraged by a fund kindly placed at my disposal by the Secretary of the Smithsonian Institution.

† Cf. S. P. Langley: "The Internal Work of the Wind," Smithsonian contributions, No. 884, 1893, Washington, D. C.

‡ Considerations of this kind originated, I believe, with the late Prof. Balfour Stewart. Recently the subject has been attacked more seriously, notably by Prof. F. H. Bigelow.

§ Barus: Bulletin U. S. Geological Survey, No. 96, p. 29, 1892. Cf. Proc. American Acad., XXV, p. 106, 1890.

by Prof. Worthington,* and in a more elaborate article by Prof. Greenhill.† There is not much succor to be gained from theory. The most lucid expression of the case is due to Lord Rayleigh.‡ His explanation meets the conditions of the present paper very fully, since the gauges are to be constructed with sharp edges and a spindle-shaped section, in order that the changes of shape occurring may be pure bending. § 8. Stretching would necessarily introduce resistances large as compared with the feeble forces to be measured. Since in the flexure of an inextensible surface, the product of the principle radii of curvature at a point of the surface remains constant (Gauss), any uniform sectional flattening of the walls of the tube due to increased external pressure must be compensated by an increased curvature of the axis; and vice versa.

If the edges are sharp, there seems to be no advantage in increasing the height of the section, for the elastic resistances increase at the same time as the external pressure. There is, on the other hand, a disadvantage in wide tubes, for the length of the helix is thereby necessarily increased and the curl made more cumbersome, while the shape of the section cannot long remain regularly and uniformly arched.

Simple curls.

3. *Apparatus.*—There is, therefore, a demand for extremely thin metallic tubes, flattened nearly to the point of actual contiguity of the walls and left with almost sharp edges. Tubes made of metal as thin-walled as $0{\cdot}01^{cm}$ are manufactured abroad;§ but American makers usually fall short of this remarkable accomplishment. I found, however, that it was quite possible to derive full advantage from the American tubes by *dissolving* off the outside layers in a suitable acid bath.

The tube at my disposal was made of copper, being like the material I formerly used in my calorimetric work.‖ This metal is elastically unpromising, apart from the technical advantages of smooth solution in diluted nitric acid, of easy flattening and bending, and of a small modulus of elasticity. Results, however, which can be obtained with copper tubes, can be much improved by the use of other more suitable metals, and for this reason the data of sensitiveness and constancy obtained would be an index of the possibilities of the gauge erring markedly on the side of safety.

Two methods suggest themselves for flattening: the tube

* Worthington: Nature, xli. p. 296, 1890.
† Greenhill: Nature, xli, p. 517, 1890.
‡ Rayleigh: Proc. Roy. Soc., Dec., 1888.
§ I owe most of my information in relation to thin tubes to Prof. Langley.
‖ Barus: Proc. Am. Acad., xxvi. pp. 316–317, 1891. The liquid was examined in a very thin tubular helix of copper, to insure rapid cooling in the calorimeter.

may either be compressed between steel rollers, then neatly coiled on a steel mandrel at the lathe with the turns one or two millimeters apart, so that the finished tube has the general form of a curl, and finally dissolved to the required thinness of wall in the nitric acid bath; or the tube may first be dissolved to the required lightness, then flattened and coiled as stated. The second of these methods is the best, though it requires a long tubular bath with a cistern at the top to avoid spilling the acid during the more or less violent effervescence in solution. The ends of the tube are stopped with corks, covered over with a cement of resin and beeswax, and all imperfect parts of the tube are similarly protected. The progress of solution is tested by taking weights from time to time, and when the tube is so light as to begin to float, it is suitably held down. A spring balance arrangement attached to the tube and out of the reach of the acid fumes, obviates the need of repeatedly removing the tube from the bath. Holes are sometimes eaten through the walls at defective places, probably from galvanic action. Should this occur, the tube must be cleaned at once, and cut apart at the defective place.

The first of the methods sketched above is more convenient, as the curl requires a much smaller bath. Unfortunately solution is most active at the edges; the tube becomes very fragile and is in danger of fissuring on continued use.

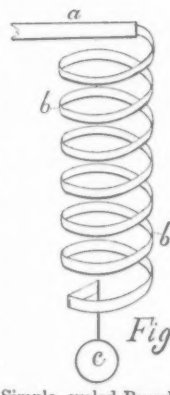

Fig. 1.

Simple curled Bourdon tube.

Tubes rolled down and coiled under a tense pull are apt to be quite closed. The way in which this can be remedied by *counter-twisting* will be described below (§ 8, et seq.), where closed tubes may even be an advantage. But in this place it is best to stretch two fine wires of brass or copper (say $0{\cdot}02^{cm}$ in diameter) from end to end of the tube, so that complete closure is avoided.

An interesting structural result was observed in this work. Open helices, with the turns about $0{\cdot}3^{cm}$ apart, after solution became closed helices with the turns all but touching at the edges, showing that the layers of the metal were subjected to unequal strains with a maximum of deformation at the outside.*

As a rule tubes must first be cleansed internally (to remove pulverulent or fatty matter) with ammonia, hydrochloric acid and water, and then thoroughly dried by a current of warm air. The finished curl is closed at one end, with the other

* Compare this with the gradual loss of explosive tendency of a Prince Rupert drop, when the external layers are successively etched off (Barus and Strouhal,

soldered to a suitable terminal tube to connect it with the air pump. The accompanying figure 1 shows the curl ready for experiment; *a* is the terminal tube leading to the air pump, *bb* the curl aneroid, *c* a mirror or other form of index, to register the rotation of the lower end of the curl relatively to the upper, when the air within is being exhausted. For convenience in drawing only a few turns of tube are shown in the figure.

4. *Results.*—In the first experiments the object sought was some *guidance* as to the effect of varying the diameter of the curls. Copper tube, with walls $0{\cdot}025^{cm}$ thick, was flattened till the spindle-shaped section was about $0{\cdot}5^{cm}$ high and $0{\cdot}08^{cm}$ wide, then wound so as to make an open helical spring. The diameter of the curl was successively reduced by winding on smaller mandrels, and the corresponding sensitiveness was found by comparing the curl with a mercury gauge when both were joined to the receiver of a Sprengel pump. The index at the bottom end of the centered curl moved over a graduated circle about a foot in diameter and divided in quarter degrees.

Table 1 contains an example of the results. The curl lengths are approximate, due to unavoidable irregularities of winding. In addition to the direct readings I will give the pressure difference in centimeters of mercury per degree of deflection (i. e. per degree of deviation between the terminal tangents of the helix), and the same datum taken per turn of the curl and per centimeter of the length measured along the turns of the helix. In general pressure denotes the difference of pressure between the outside and the inside of the tube and is always given in centimeters of mercury.

It appears therefore, that within the range of accuracy of these experiments, the untwisting of the curl in degrees of arc is very nearly proportional to the pressure difference in cm. of mercury, remembering that the pressure on the outside of the tube acts on the cistern of the barometer. In the second place, the sensitiveness of the coil for a given length of tube is somewhat greater for small radii than for large radii; thus for the diameter $3{\cdot}1^{cm}$, a degree of arc corresponds to $4{\cdot}07^{cm}$ of mercury, whereas for the diameter $2{\cdot}0^{cm}$, a degree corresponds to $3{\cdot}5^{cm}$ of mercury. The changes, however, are small and irregular and possibly largely influenced by temperature, which was not taken. At all events, the data for cm. of mercury per degree of deflection, per turns of curl, increases so rapidly, that in view of the objectionably great length of curls of small diameter, they offer no advantage. As a rule the diameter $2{\cdot}8^{cm}$ will be adhered to in the present paper.

this Journal, xxxii, p. 182, 1886); and with another result (this Journal, xxxiv, p. 183, 1887), in which the limit of torsional resilience of soft iron was reached whenever the obliquity of the external fiber of the wire exceeded about 0·003 radians.

TABLE 1.—*Behavior of Curls of different diameters, for the same length of tube coiled to a helix.*

Description of curl.*	Mercury Manometer.	Inflection of curl.	Cm. of Hg per degree of arc.	Cm. of Hg per degree per turn.	Cm. of Hg per degree per cm. of diameter.
Diam. of curl $3{\cdot}1^{cm}$	cm	°arc			
Turns of curl 21	76·7	18·7	4·07	85	1·3
Length of curl 18^{cm}	67·9	16·6	4·07		
	61·5	15·0	4·08		
	54·3	13·2			
	41·5	10·1			
	32·1	7·8			
Diam., $2{\cdot}8^{cm}$	76·3	21·1	3·55	87	1·5
Turns, 24	70·5	19·5	3·55		
Length of curl $19{\cdot}5^{cm}$	65·3	18·0	3·57		
	59·8	16·4	3·63		
	52·5	14·4			
	47·4	13·0			
	41·4	11·3			
	29·3	8·0			
Diam., $2{\cdot}0^{cm}$	60·3	17·4	3·45	121	1·7
Turns, 35	52·0	14·9	3·49		
Length of curl 22^{cm}	31·0	8 9			
	0·0	0·0			

Practically, in estimating the effect produced on thinning the walls by etching, I may therefore either express the number of cm. of mercury which correspond to a degree of arc per turn of the tube, in which case the same diameter should occur throughout or be specified; or I may make similar reference to the diameter; or finally (and probably best), I may state the centimeters of mercury per degree of deflection, of the coil per unit (cm.) of length of the tube used in winding the curl. Lumping the results of Table 1, where the length of tube used was about 210^{cm} throughout, it appears that in these initial experiments a pressure of about 780^{cm} of mercury would produce 1° of deflection between the ends (tangents) of a tube 1^{cm} long, and having the size and thickness specified.

The endeavor was now made to dissolve down this curl, but the action was carried too far and it was eventually lost in the process. After about $\frac{1}{3}$ of the weight had been etched off however, 61^{cm} of mercury corresponded to a degree of twist per turn for the diameter of curl $2{\cdot}9^{cm}$, or 550^{cm} of mercury per linear cm. per degree, showing a decided gain over the general data† of Table 1.

5. Another curl, No. V, was now wound, etched off and tested with the following results, after having been exhausted for some time. The original weight was 39^{g} and after etching

* The length of the curl and the length of the tube used in winding the curl must be carefully distinguished.

† A slight digression was made in coiling the next tube like a watchspring; but the experiment showed no special advantages.

20^g, so that the walls must have been reduced in thickness from 0·025^{cm} to about one-half this value,

Diam. of curl, 2·8^{cm}	Pressure,	71·9^{cm}, Hg	Deflection, 111°
Turns of curl, 22		59·5^{cm}	97°
Length of curl 14·7^{cm}		0·0	20°
	(later)	0·0	0°
	(next day)	0·0	−2°

Pressure per degree of arc per turn, 14·6^{cm}, Hg.
Pressure per degree per linear cm., 130^{cm}, Hg.

There has therefore been a considerable gain in sensitiveness,* inasmuch as the deflection of one degree between the ends of a linear centimeter of the coiled tube is now equivalent to 130^{cm} of mercury. A new feature has been introduced in the apparent occurrence of marked viscosity, as shown by the gradual displacement of the "zero" reading for pressure difference. The cause of this will be further studied, but it is probably due to the tendency of external pressure to quite close the tube,† so that it takes the air some time to reënter.

This curl was now cut in two parts, V_a and V_b, of 9·5 and 11 turns respectively, in order to test whether the air had quite reached the extreme parts of the tube. An examination showed the following results:

			Pressure:	Deflection:
V_a	Diameter of curl, 2·88^{cm}		72·0^{cm}, Hg	49·6°
	Turns of curl, 9·5		64·3	43·7°
	Length of curl,		55·8	38·3°
			33·3	23·4°
			0·0	1·6°
		(later)	0·0	0·0°
	Pressure per degree per turn, 14·0^{cm}.			
	Pressure per degree per linear cm., 122^{cm}.			
V_b	Diameter of curl, 2·8^{cm}		62·7^{cm}, Hg	56·3°
	Turns, 11		53·9	49·6°
	Length,		46·2	43·8°
			35·6	35·3°
			0·0	7·9°
		(later)	0·0	0·0°
	Pressure per degree per turn, 14·3^{cm}.			
	Pressure per degree per linear cm., 127^{cm}.			

These results agree substantially with the data for the uncut curl, the discrepancies being due to the difficulties of estimating the number and diameter of the turns and to the occurrence of viscosity. It is seen that viscosity has in no way disappeared, though it is much more marked in V_b than in V_a.

* Data of the table taken in accord with other similar experiments on the same curl.

† There may also be a displacement of the zero due to friction of the walls of the tube on each other. Such displacement, however, would probably be permanent.

From this it follows that the viscosity in question must be in large measure *apparent* but not real. While V_b was preserved for other purposes, V_a was now further etched off. In so doing some of the turns had to be sacrificed, being eaten through. The results in these cases were more irregular, and apparent viscosity more marked. I will not therefore give them in full. After the first solution, 9 turns of V_a showed 13^{cm} pressure per degree per turn, or 107^{cm} Hg per degree per linear cm. After the second solution V_a showed $8{\cdot}7^{cm}$ pressure per degree per turn, or 77^{cm} pressure per degree per linear cm. It was imposible to carry the solution further, because the edges were too thin to withstand flexure without fissuring; but the walls were $0{\cdot}01^{cm}$ in thickness, and might easily have been reduced. cf. § 3.

Summary.—Remembering, therefore, that if viscosity were excluded, the curl would have been more sensitive, I may state that it takes from 50^{cm} to 75^{cm} of flat copper tubing, the walls being $0{\cdot}01^{cm}$ thick, to make a curl aneroid such that a degree of arc shall correspond to 1^{cm} of the barometer. If, therefore, the reading be made with mirror and telescope, with the scale at a distance of 286^{cm} from the mirror, 10 linear cm. of the scale correspond to 1^{cm} of the barometer. If the tube be wound on a mandrel a little over $2\,8^{cm}$ in diameter, 7 or 8 turns would suffice, and the length of the curl need therefore not exceed 8^{cm}. Hence, 10 such curls joined in series end to end and suitably supported, would show 100^{cm} at the telescopic scale per cm. of the barometer, and the curl would be less than a meter long. § 12.

Counter-twisted Systems.

7.—In the results thus far, the object has been merely to exhibit the possibilities of the curl aneroid. If the apparatus is to attain precision, the apparent viscosity must be brought quite under control, and the effect of the temperature of the medium evaluated and reduced to the smallest margin. I have in a measure fulfilled both these conditions by using counter-twisted systems in the way presently to be specified. As a first step in this direction, I will cite some data obtained with curl VIII, in which two fine brass wires (diameter $0{\cdot}02^{cm}$) were drawn through the tube before flattening and coiling. The walls were $0{\cdot}013^{cm}$ thick, and all but 5·2 turns were lost during solution.

Diam. of curl,	$2{\cdot}8^{cm}$	Pressure, $73{\cdot}7^{cm}$, Hg.	Deflection, 38·3°
Turns,	5·2	63·2	33·4°
Length of curl,	$3{\cdot}3^{cm}$	48·5	26·0°
		0·0	0·6°
		0 0	0·0°

Pressure per degree, per turn, $10{\cdot}4^{cm}$.
Pressure per degree, per linear cm., 91^{cm}.

The small residue of viscosity left here is very probably not even yet a true phenomenon, i. e. it is due to strictures which prevent the free passage of air, and to friction between the contiguous walls of the tube and wire; but the improvement over the preceding cases is obvious.

8.—To enter into this question somewhat more fully and from a different point of view, a wider tube was selected (the walls of which were but $0{\cdot}12^{cm}$ thick), flattened and coiled *without* closing the section. Indeed a blunt edge was left and the section was about $0{\cdot}06^{cm}$ broad and $1{\cdot}6^{cm}$ high. The data for this coil (IV) were as follows:

Diam. of curl,	$3{\cdot}2^{cm}$	Pressure, $75{\cdot}9^{cm}$, Hg.	Deflection, $11{\cdot}1°$
Turns of curl,	4·5	69·5	$10{\cdot}3°$
Length of curl,	$14{\cdot}0^{cm}$	57·8	$8{\cdot}8°$
		41·3	$6{\cdot}6°$
		36·8	$5{\cdot}9°$
		0·0 zero.	$0{\cdot}0°$

Pressure per degree, per turn, $32{\cdot}5^{cm}$.
Pressure per degree, per linear cm., 330^{cm}.

In this curl there is no evidence of viscosity, but the relation of pressure-difference and deflection is not quite linear, as was the case with sharp-edged coils. The data are mean ratios. The sensitiveness (330^{cm}, Hg, per degree per linear cm.) is of low order, in spite of the thin walls ($0{\cdot}012^{cm}$) and broad tube. § 2.

This curl was now replaced on the metallic mandrel, and the edges hammered quite sharp from end to end. On removing the curl from the mandrel I found that *no air* could be sucked through it. The walls, therefore, overlapped each other, *imperviously* to air. When, however, the curl was somewhat uncoiled in the hands, the air came through quite freely. This suggested a novel method of making the curl aneroid, requiring no inclosed wires, and partaking of other advantages, since the uncoiling can be done with a suitable spring. In a counter-twisted system of this kind:

(1.) The sharp-edged coils can be opened by an amount compatible with the free access of air. Therefore this system is adapted for extreme sensitiveness.

(2.) The system is differential; or, in other words, the *differences* of viscosity and of elasticity of curl and spring, and the *differences* of the thermal variations of these quantities come into play. Thus if a spring and curl could be made having the same effective viscosity* and the same thermal coefficients of viscosity and elasticity, respectively, *the system would be perfectly elastic and independent of temperature;* or,

* Depending therefore both on the material and on the lengths of the two helices.

(3.) If the adjusted curl aneroid, exhausted and therefore twisted by external pressure, be untwisted to the same degree by the spring, the curl is now nearly without strain, excepting such of higher orders; and the viscosity and thermal relations of viscosity and rigidity of the counter-twisting spring alone come into play. Hence a metal of low rigidity may be chosen for making the curl, while the counter-twisting spring is selected for high viscosity. One would use, for instance, hard steel annealed at 400° or even a sufficiently thick quartz fiber.

It is clear that the counter-spring must be weak, so that it may make a number of rotations for each rotation of the curl; for the resistance of the counter-spring is incremented at the expense of the deflection of the curl. Hence a long fiber, or spiral spring, or a watch spring is adapted. Finally, to prevent knotting of the spring, a weight is (*temporarily*) added to the system, preferably suspended in a basin of water to deaden vibrations. The curl aneroid has now taken the form of figure 2, where *cc* is the curl, communicating at one end, *k*, with the air pump. The other end is closed and carries the horizontal, radial stylus *f*, to which the stiff wire *dd* of the spring *bb*, the mirror *e* and the damping plate *g* are attached symmetrically to the curl. The plate *g* is of lead, thus serving as a weight (as well as a damper) to pull out the spring *bb*. A dish *h* (shown with *g* in cross section) containing a liquid, surrounds *g*. The spring *b* is attached above to a rigid clamp at *a*, by means of a stiff wire *l*, the clamp (not shown) being so constructed that the spring can be both raised and twisted.

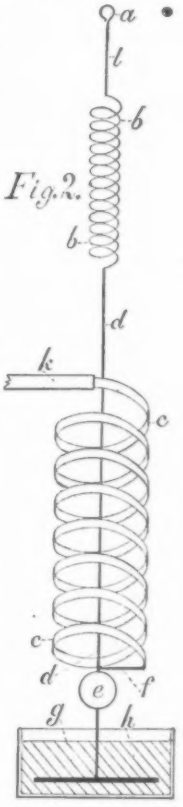

Fig. 2.

Counter-twisted system of curled Bourdon tube, spring and appurtenances.

The weight *g* and the damping arrangement are only permissible in calibration work like the present. If the registry of the aneroid is to be instantaneous, the mass must be kept down to the lowest limit possible, and no ballast is to be attached. Hence a delicate watch-spring, or a double helical spring is preferably employed, and a suitable method of damping vibrations must be investigated. An elastic fiber fastened at both ends, with the end of the helix attached near the middle, is also contemplated.

9.—To obtain preliminary evidence, I took curl IV, just discussed (§ 8), though it had become somewhat leaky from hard usage. The counter-twisting was done by a long steel wire with the following results:

Turns uncoiled from 4·5 to 3·7. { Pressure per degree, per turn, $13{\cdot}4^{cm}$, Hg. Pressure per degree, per linear cm., 167^{cm}.

Turns uncoiled from 4·5 to 3·0. { Pressure per degree, per turn, $5{\cdot}1^{cm}$, Hg. Pressure per degree, per linear cm., 79^{cm}.

In all these cases the deflections were instantaneous, and there was no apparent viscosity. The curl itself has been improved from one of low sensitiveness (330^{cm}) to nearly the same range of high sensitiveness (77^{cm}), actually obtained in § 6 for extremely thin copper tubes.

This result deserves special study: but it already appears that so long as the coil is sharp-edged in section—so long as the strain is a case of nearly pure bending—the coil increases in sensitiveness as its spindle-shaped section is more highly arched. The smaller the medial radius of curvature of a right section of the tube, the greater proportionately is its variation for the same pressure-difference; and the greater proportionately must the corresponding variations of the longitudinal radius of curvature (coil radius) also be, since the product of two radii is to remain constant. Hence *a rotundly arched, spindle-shaped section, maintained in an excessively thin-walled tube, is compatible with the greatest amount of rotation at the registering index.*

10.—A copper tube having walls $0{\cdot}01^{cm}$ thick was flattened and rolled down as usual. The curl (No. VII) contained 9 turns and it was $2{\cdot}8^{cm}$ in diameter and about $12{\cdot}5^{cm}$ long, each turn in section being $0{\cdot}8^{cm}$ high, with blunt edges about $0{\cdot}05^{cm}$ wide. So constructed, the sensitiveness (conformably with the data in § 8) was low, for the pressure in cm. Hg per degree per turn was 50, and the pressure per degree per linear cm. of the curl 440^{cm}.—in spite of the thin copper walls stated. This tube was now hammered flat and sharp-edged on the steel mandrel. A part, VII_b, free from flaws was then cut from this tube and used in the following tests, Table 2. For want of better material a helical spring of brass spring wire was used in the counter-twisting and the system was weighted to prevent knotting (cf. § 8).

These results are given graphically in the chart figure 3, where the ordinates are pressures in cm. of mercury, corresponding to a deflection of 1° for a length of 1^{cm} measured on the turns of the curl. The abscissas show the amount of counter-twisting at the lower end of the system in degrees. The sensitiveness therefore increases in marked degree with

the amount of counter-twisting, and apparently reaches a limit at about 150°. From here on, however, the evidences of permanent set were met with. They are in the direction of the uncoiling, showing the spring to have acted on the curl. At the end of the experiment, when the spring was released, about 90° of permanent set had been imparted to the curl. I believe therefore, that the curl could have been made even more sen-

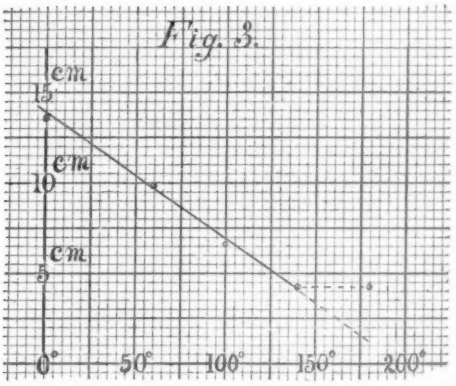

Chart showing the inverse sensitiveness (ordinate) of a counter-twisted system varying with the amount of counter-twist (abscissa).

sitive than shown in figure 3, if its material had been resilient and of high viscosity. At all events, the datum reached (50^{cm} Hg corresponding to a degree of deflection between the ends of a linear cm. of the turns of the curl) is markedly in excess of the results given at the end of § 7, while the apparent viscosity of the metal has now no serious significance. Indeed since the viscous set above was actually negative (uncoiled curl), whereas in the simple curl (§ 5 et seq.) it is positive, a virtual elimination of viscosity is clearly possible.

TABLE 2.—*Showing the increased sensitiveness resulting from increased counter-twisting.*

Turns of VII$_b$ No.	Counter-twist in degrees of arc. °	Pressure per degree, per turn. cm., Hg.	Pressure per degree, per linear cm. cm., Hg.	Remarks.
2·5	0	13·6	120	No viscosity.
2·3	60	9·9	95	" "
2·1	100	6·6	69	" "
1·9	140	4·3	50	" "
1·7	180	4·3	56	Curl shows negative viscosity.
2·3 (released)	0	10·0	98	Curl shows 90° set after releasing spring.

11.—I want finally to put the remarks made in the above paragraphs to an actual test in continuous series of measurements with mirror and scale. A figure of the apparatus is given in § 8. A curl, No. II, was wound for the purpose, of copper tube. A very small leak was purposely left, so that the exhausted curl might gradually (several days) fill with air, while comparison with the attached mercury manometer were in progress. Preliminary tests made on the graduated circle showed the following results:

Description.		Pressure.	Deflection.	Pressure per degree.	Pressure per degree, per turn.	Pressure per degree, per linear cm.
Diameter curl,	$2{\cdot}8^{cm}$	cm., Hg.	°arc.			
Turns,	15·5	76·80	84·75	0·926	14·1	124
Length,	12^{cm}	57·92	64·80	0·894		
		40·70	45·75			
		0·0	0·0			

The relation is not linear, though the discrepancy may be thermal. The curl is only *moderately* sensitive (for in § 10 this sensitiveness has been doubled), and not quite free from viscosity. It is therefore interesting to see in how far precision can be obtained with this short and not very favorable coil, when suitably counter-twisted.

The spring used in counter-twisting was of brass spring wire, $0{\cdot}05^{cm}$ diameter. It consisted of 31 turns about $1{\cdot}5^{cm}$ in diameter and when stretched was $1{\cdot}7^{cm}$ long. The counterpoise weighed something over 25^{g}.

The system was adjusted by first exhausting the curl aneroid to a nearly perfect vacuum, after which the mirror was brought back to its original position (that is before exhausting) by the spring. There was thus but little strain left in the curl. The method adopted was therefore the third in § 8.

A thermometer hung beside the mercury manometer and the curl, giving the temperature of both, though not closely enough (as observation showed). A fine bulb thermometer placed within the coils is essential. The scale was at a distance $3{\cdot}5^{met}$ from the mirror.

Of the two continuous series of observations made I shall, for brevity, only give an example of part of the second. The first is defective in temperature. Table 3 contains the results, showing in the first three columns the height (b) of the mercury in the manometer (reduced to 0° C.), the temperature (t) of the air near the curl, and the reading (s) in the telescope of the deflections of the curl. Observations were made in groups of four or more, during different parts of the day for different days. Temperature was very variable, thus adding to the severity of the test.

The column headed B is the virtual barometer, to be obtained in a way presently to be given.

TABLE 3.—*Showing the behavior of the curl aneroid as compared with the mercury manometer.*

b	s	t	B	b	s	t	B
Manometer. cm., Hg.	Curl. cm.	Temperature. °C.	Manometer at 25°. cm., Hg.	Manometer. cm., Hg.	Curl. cm.	Temperature. °C.	Manometer at 25°. cm., Hg.
75·49	54·75	25·6	75·53	75·69	58·80	29·0	75·99
74·89	49·40	25·8	74·95	75·16	54·30	28·8	75·44
74·58	46·70	26·0	74·65	74·36	46·30	28·4	74·61
73·95	40·30	26·3	74·05	72·97	32·00	28·0	73·19
75·58	56·50	27·3	75·75	76·06*	57·40	23·1	75·92
75·38	54·60	27·3	75·55	75·29	50·70	23·1	75·15
74·95	50·60	27·5	75.14	74·72	45·00	23·2	74·59
74·66	47·90	28·0	74·88	74·02	38·40	23.6	73·92
75·59	57·60	29·2	75.90	76·01	58·00	23·5	75·90
75·15	54·00	29·6	75·50	75·69	54·90	23·5	75·58
74·22	44·70	30·0	74·59	75·18	50·00	23·5	75·07
73·89	41·60	29·8	74·24	74·76	45·80	24·2	74·70
75·57	57·90	30·2	75·96	76·46†	60·70	21·8	76·22
75·35	56·50	30·2	75·74	75·70	54·55	22·3	75·50
74·95	52·30	30·0	75·32	75·22	50·50	22·8	75·05
71·92	21·10	29·6	72·25	73·94	37 85	23·4	73 82
75·54	57·45	29·4	75·87	76·36	63·00	26·0	76·44
74·95	52·40	29·2	75·26	75·86	57·30	26·1	75·92
74·45	46·60	29·2	74·76	75·42	54·50	26.3	75·52
74·02	42·70	29·2	74·33	74 78	47·60	26·2	74·87
75·64	58·50	29·4	75·97	76·34‡	57·60	20·8	76·02
75·16	54·30	29·4	75·49	75·93	54·65	21·0	75·63
74·33	45·80	29·1	74·63	75·49	51·10	21·2	75·20
73·38	36·10	29·0	73·67	74·86	45·20	21·6	74·61

* One day after. † Three days after. ‡ Four days after.

If the deflections (s) are platted as a function of the pressure (b,) a series of detached lines are obtained, which usually lie at some distance apart and are not quite straight even for a single group. Inspection shows these discrepancies to be principally due to temperature. It is not at once obvious how the temperature coefficient is to be computed, unless it be assumed, conformably with § 4, that the corrected loci are really straight.

The following is a method of calculating the temperature corrections without entering into unduly complex computations: Let s be the deflection (scale reading) at the pressure b and the temperature t; let s', b', t' have a similar relation, and let s_0, c and α be constants. For any two groups, put

$$\begin{aligned}(s+s_0)(1+\alpha t)&=bc,\\(s'+s_0)(1+\alpha t')&=b'c.\end{aligned}\qquad(1)$$

If by aid of the chart of detached lines just referred to, the values of b be taken for $s=s'$, then

$$\alpha=\frac{b'-b}{bt'-b't}\qquad(2)$$

Proceeding thus, I found $\alpha = 0{\cdot}001$; and with this value I reduced the observations by placing (1) under the form

$$s = \frac{b}{1+\alpha t} c - s_0 = Bc - s_0 \qquad (3)$$

Hence s is a linear function of B; and this postulate can be tested graphically without computing c and s_0. B is given in the last column of Table 3.

The conditions under which these data were obtained were very unfavorable. As a result of the delicate suspension, the jar of wagons and cars passing the laboratory often made it impossible to read the scale millimeters in the telescope. Moreover I was unprepared for so large a temperature coefficient, α, as has just been adduced; and I did not therefore take such special precautions against currents of air which should have been taken, seeing that the thin metallic helix adjusted itself at once to temperature, whereas the thermometer follows sluggishly after. Nor was the latter placed near enough to the coil. Hence since a single degree of temperature corresponds to nearly $0{\cdot}1^{cm}$ of the barometer, discrepancies* of half a millimeter of pressure must have been incident to the work, and the table and chart bear this assertion out. Points which lie out of position are isolated in each group and the discrepancy is the result of a current of air.

In spite of the unfavorable choice of metals (copper and brass) the behavior of the copper curl is thus seen to be satisfactory so far as the present purposes go: for a development of principles of construction has only been aimed at. The telescope reading for this small curl is $9{\cdot}8^{cm}$ per cm. of the mercurial barometer.

12. *Conclusion.*—Having reached this stage of progress, it seemed expedient to break off the work, for it would not be worth while to proceed with fine measurement without making the system of more highly viscous material at the outset. In brief: tubing preferably of resilient brass 3–4 millimeters in diameter or less, with walls $0{\cdot}01^{cm}$ thick or less (by solution) is desirable. The tube should be heated in steam to remove excesses of drawn strain and thereafter flattened and coiled until the walls all but touch. The counter-twisting spring is to be either helical or watchspring-shaped, and of steel annealed at 400° C., or a suitable long quartz fiber. A long curl would not be self-sustaining; but it could be made so without interfering with its free action, by a series of equidis-

* In the face of the large thermal effect discussed in the text it would be useless to endeavor to evaluate the effect of viscosity. Nor would a metal of low viscosity, like a spring of drawn brass, be chosen in tests of a final character.

tant radial spokes attached at the inner face of the curl with their central ends fastened to a fiber of silk.

If, therefore, the conditions investigated at the end of §§ 6, 10, be called to mind, a non-differential curl aneroid (§ 8, case 3) less than a meter long, provided with a mirror for registry, will give account of variations of atmospheric pressure of a thousandth of a millimeter of the barometer, provided the mounting is sufficiently free from tremor, and temperature be kept constant to a few thousandths of a degree during the interval of observation.

These conditions will be much less severe if the parts of the counter-twisted system are especially chosen (as stated in § 8, case 2) and twisted with reference to viscosity, rigidity and temperature. Indeed the chief result of the present paper is the exhibition of the properties of the counter-twisted system. A continuous mechanism has been brought forward which not only minimizes the hurtful effects of viscosity and of the thermal changes both of viscosity and of rigidity, but which accomplishes these desirable results in such a way as to remarkably increase the sensitiveness of the instrument.

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ART. XVI.—*Fayalite from Rockport, Mass., and on the Optical Properties of the Chrysolite-Fayalite Group and of Monticellite;* by S. L. PENFIELD and E. H. FORBES.

IN the fall of 1890, Mr. J. H. Sears of the Peabody Academy of Science, Salem, Mass., while visiting the Rockport Granite Quarry, found a crystalline mass of a dark colored mineral, which proved on examination to be fayalite. The occurrence of this mineral is so unusual that it was considered worthy of a special investigation and was sent for that purpose to the Mineralogical Laboratory of the Sheffield Scientific School.

The material offered an excellent opportunity for an investigation of the optical properties of fayalite, which had never been determined, and the results were of such a nature that it seemed best to extend the study to the different members of the chrysolite group, in order to determine the effect upon the optical properties due to the mutual replacement of iron and magnesium.

Fayalite.

The material from Rockport was a crystalline mass, found at a depth of 60 feet, near the base of a large boss, or vein of

pegmatite. It occurred at one side of the pegmatite vein in the massive hornblende-biotite granite, as a lenticular shell of varying thickness, about 12 to 16 inches in diameter, filled on the inside with loose earthy material and enveloped by a layer of magnetite about one inch thick.

The material showed no crystal faces, but two distinct cleavages at right angles to each other. The color of the mineral on a fresh fracture is a dark resinous green, but thin edges transmit a yellowish light. On examining fragments with a microscope it was found that they were fresh and transparent, but permeated with grains of magnetite. The material for analysis was therefore prepared by pulverizing and sifting to a uniform grain and freeing from magnetite with a magnet. The material thus prepared was of exceptional purity. The specific gravity taken with the pycnometer and the results of the analysis are as follows:

Specific gravity 4·323, 4·316, 4·317. Average 4·318

	I.	II.	Average.	Ratio.		
SiO_2	30·11	30·05	30·08	·501		1·00
FeO	68·04	68·19	68·12	·946		
MnO	·77	·65	·72	·010	1·004	2·00
H_2O	·88	·87	·80	·048		
Total	99·80	99·76	99·80			

The ratio indicates almost pure ferrous ortho-silicate Fe_2SiO_4 with only a trace of manganese and no magnesia, although a careful test was made for the latter. The small amount of water is considered as basic. A high temperature is needed to expel it, and limonite, the most likely mineral to be formed by decomposition, was wanting. If the water is disregarded, the analysis shows a slight excess of silica.

The cleavages served for the orientation of the optical properties and plates cut parallel to these, as described by Penfield and Pratt,* proved to be parallel to the pinacoids 001 and 010. The first of these gave no interference figure in polarized light, while the second showed the emergence of the acute bisectrix. The divergence of the optical axes was measured on a large Fuess axial angle apparatus, and although it could be measured in air, it was found best to measure it in α-monobromnaphthalene. The plates also served for determining the pleochroism.

The indices of refraction were obtained from prisms carefully oriented by the cleavages. The results are as follows: for yel-

* This Journal, vol. l, p. 387, 1895.

low Na, $\alpha = 1{\cdot}8236$, $\beta = 1{\cdot}8642$, $\gamma = 1{\cdot}8736$, $\gamma - \alpha = {\cdot}050$, the orientation being $a = c$, $b = a$, $c = b$ as in crysolite.

The plane of the optic axis is the base and a is the acute bisectrix. The double refraction is, therefore, negative. The dispersion is $\rho > \nu$, 2H, Li = 57° 27′; 2H, Na = 56° 32′; 2H, Tl = 55° 2′. The index of refraction for α-mono-bromnaphthalene being 1·6577 at 23° C. for yellow, $V_y = 24° 55'$ and $2E_y = 103° 25'$. $2E_y$ was also measured and found to be 103° 4′. From the values of α, β and γ, according to the usual formula, V_o was found to be 64° 42′, hence $V_a = 25° 18'$, agreeing closely with 24° 55′ as given above. The pleochroism is distinct, in sections about 0·5^{mm} thick for rays vibrating parallel to b orange yellow, parallel to a and c greenish yellow.

To make sure of the orientation of the optical properties as given above, where only cleavages were available, a comparison was made with the excellent crystals from the obsidian of the Yellowstone Park described by Iddings and Penfield.* For this purpose, material was supplied by Mr. Arnold Hague of the U. S. Geological Survey, to whom the authors desire to express their thanks. On these transparent, but minute crystals, the basal cleavage and the emergence of the obtuse bisectrix at right angles to the pinacoid 100 were distinctly seen, the plane of the optic axis being 001. No indication of a cleavage parallel to the pinacoid 100 was observed on the fayalite from Rockport, and the statement in many mineralogies of a cleavage in that direction is probably erroneous.

Hortonolite.

Under this name Professor Brush† has described a member of the chrysolite-fayalite group, found in an iron mine at Monroe, Orange Co., N. Y., and characterized by its dark color and high iror percentage. In appearance it resembled the fayalite from Rockport. In order to ascertain the chemical composition of the mineral upon which the optical properties were to be determined, a new analysis was made upon material from a large mass, showing cleavage in two directions, which served for the optical orientation, this cleavable material being better adapted for optical work than the crystals at our disposal.

Grains of magnetite were disseminated through the mineral and the material for analysis was therefore purified as described under fayalite.

The results of the analysis are given below, together with those obtained by Mixter and quoted by Brush:

* This Journal, vol. xxx, p. 58, 1885.
† Ibid., vol. xlviii, p. 17, 1869.

Specific gravity 4·047, 4·030, Average 4·038.

	I.	II.	Average.	Ratio.			Mixter. Sp. gr. 3·91
SiO_2	33·60	33·94	33·77	·562	·562	1·00	33·59
FeO	47·19	47·32	47·26	·656			44·37
MnO	4·76	4·32	4·54	·064	1·093	1·95	4·35
MgO	14·02	13·74	13·88	·347			16·68
H_2O	0·48	0·48	0·48	·026			K_2O 0·39
							H_2O 0·26
	100·05	99·80	99·93				99·64

The ratio of the $SiO_2 : RO = 1 : 1·95$ or nearly 1 : 2, giving the formula $(FeMgMn)_2SiO_4$, and, therefore, the mineral holds an intermediate position between fayalite and the iron-rich chrysolites. The cleavages are poorer than in fayalite, but parallel to the same faces 001 and 010. Plates and prisms were prepared as in fayalite, the optical orientation and the character of the double refraction being the same.

The following results were obtained:

For yellow light Na, $\alpha = 1·7684$, $\beta = 1·7915$, $\gamma = 1·8031$, $\gamma - \alpha$ ·0347. 2H, Li = 76° 59′; 2H, Na = 76° 00′; 2H, Tl = 75° 45′; hence with n Na for α-mono-bromnaphthalene = 1·6567 at 25° C., $V_{ay} = 34° 42'$. From the values of α, β and γ, V_o was found to be 54° 55′; hence $V_a = 35° 5'$, which agrees closely with V_a as given above. The pleochroism was similar to that of fayalite but weaker, for rays parallel to a and c very pale yellowish green, and parallel to b pale yellow.

Chrysolite.

For the optical constants of chrysolite we are indebted to Des Cloizeaux* who gives $\alpha = 1·661$, $\beta = 1·678$, $\gamma = 1·697$, for yellow Na, $2V_y = 87° 46'$, the double refraction being positive and the dispersion $\rho < \upsilon$. The amount of ferrous iron, however, is not given. He also determined the constants for fosterite, the white chrysolite from Vesuvius, containing presumably, according to the published analyses, about two per cent of ferrous oxide with the following results: $\beta_r = 1·657$, $\beta_y = 1·659$, $\beta_{bl} = 1·670$, $2V_r = 86° 1'$, $2V_y = 86° 10'$, $2V_{bl} = 86° 32'$.

Zimanyi† has recently given the following determinations on chrysolite from the East Indies, but also without any determinations of ferrous oxide; for yellow, Na, $\alpha = 1·6535$, $\beta = 1·6703$, $\gamma = 1·6894$, $2V_a = 87° 15'$.

* Memoirs De L'Institute De France, Tome xviii, p. 591.

† Zeitschrift für Krystallographie und Mineralogie, Band 22, p. 338, 1893.

For our own investigation chrysolites were selected from specimens in the Brush collection. The percentages of ferrous iron were determined by means of potassium permanganate, but unfortunately in the available material the range in the replacement of magnesia by iron was not great, leaving a wide gap in the series between the one richest in iron and hortonolite. The varieties examined are arranged below according to the decrease in the percentage of iron. The divergences of the optical axes, 2H, were all measured with yellow light, Na, in α-mono-bromnaphthalene at a mean temperature of 25° C.

Auvergne, France.—Loose crystals were chosen of a dark green color and well developed; similar to fig. 4, page 452, Dana's Mineralogy, 6th Ed. The plate for optical examination was made parallel to 010. FeO = 13·02 per cent, $\beta = 1{\cdot}6916$, 2H = 92° 1′; hence $2V_a = 89°\ 36'$.

Vesuvius, Italy.—Small loose crystals were selected of dark olive green color, showing distinct faces with 010 prominent, parallel to which the plate was cut. FeO = 12·6 per cent, 2H = 92° 9′, and considering $\beta = 1{\cdot}6916$ as in the Auvergne crystals, $2V_a = 89°\ 42'$.

Hawaii, Sandwich Islands.—The material of olive green color was collected by Prof. J. D. Dana on the southeastern shore, south of Hilo. It consisted of waterworn grains, showing occasionally a cleavage face parallel to 010 which served for orientation, and parallel to which the plate was cut. FeO = 10·3 per cent, 2H = 92° 30′, and using $\beta = 1{\cdot}678$ as given by Des Cloizeaux, $2V_o = 91°\ 2'$.

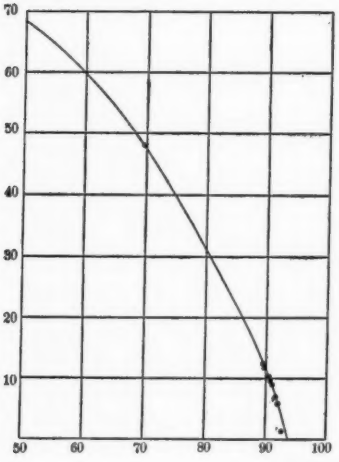
Egypt or the Orient.—A fragmentary crystal was used, of light olive green color and with crystal faces, which served for orientation. The plate was cut parallel to 100. FeO = 9·16 per cent, 2H = 89° 39′, $\beta = 1{\cdot}679$; hence $2V_a = 88°\ 41'$.

Northwestern Corner of New Mexico.—A rounded fragment was selected from material collected by the Indians and sold to lapidaries for gem purposes. The fragment showed no crystal faces, but a cleavage parallel to 010 served for orientation, and parallel to this the plate was cut. FeO = 8·6 per cent, 2H = 92° 57′, and using $\beta = 1{\cdot}678$, $2V_o = 91'\ 24'$.

The result of this investigation can be seen best from the following table, where 2V is given for yellow Na, measured over a, or the crystallographic axis *b*. The dispersion in all cases when measured in this way is $\rho > \upsilon$. The last three are the determinations of Des Cloizeaux and Zimanyi already referred to.

Material.	Locality.	Per Cent of FeO.	Axial Angle 2V measured over a.	β.
Fayalite,	Rockport,	68·1	49° 50′	1·864
Hortonolite,	Monroe,	47·3	69 24	1·791
Chrysolite,	Auvergne,	13·0	89 36	1·692
"	Vesuvius,	12·6	89 42	
"	Hawaii,	10·3	91 2	
"	Egypt,	9·2	91 19	1·678
"	New Mexico,	8·6	91 24	
"	Unknown,	?	92 14	1·678
"	East Indies,	?	92 45	1·670
Fosterite,	Vesuvius,	2?	93 50	1·657

The effect of a decrease in iron is to constantly increase the value of 2V, which, at the iron end of the series, changes much more rapidly than at the magnesia end, as may be seen by the curve which has been plotted, and where the percentages of FeO have been taken as ordinates and the values of 2V as abscissas.



The decrease in FeO is accompanied by a decrease in the value of β and also in the strength of the double refraction. With the FeO about 12 per cent 2V for yellow equals nearly 90°. Chrysolites containing less than 12 per cent FeO have c, or the crystallographic axis a for the acute bisectrix and are optically positive with dispersion $\rho < \upsilon$, and those richer in iron are optically negative with dispersion $\rho > \upsilon$.

Monticellite.

In order to make the investigation of the chrysolite group more complete, we have included monticellite $CaMgSiO_4$, which in its crystallographic relations is very close to chrysolite, the crystals from Magnet Cove, Arkansas, investigated by Genth and Pirsson* furnishing excellent material for the purpose. An abundant supply of this rare mineral was generously furnished to us by Messrs. Geo. L. English & Co. of New York, to whom we take pleasure in expressing our thanks. As

* This Journal, vol. xli, p. 399, 1891.

Genth's analysis showed a loss by ignition of 2·29 per cent and 2·03 per cent of P_2O_5, it evidently was made on impure material and consequently a new analysis seemed necessary.

The material which we were able to select was of exceptional purity and yielded the following results:

								Genth.
Specific gravity		I. 3·022	II. 3·047	Mean. 3·035				
	Analysis I.	II.	Average.	Ratio.				
SiO_2	36·86	36·70	36·78	·613	·613	1·00		33·47
FeO	4·61	4·89	4·75	·066				5·01
MnO	1·58	1·67	1·62	·023	·629	1·02		1·12
MgO	21·44	21·75	21·60	·540				20·61
CaO	34·23	34·39	34·31	·613	·613	1·00		35·25
H_2O	·97	·93	·95				Ign	2·29
							P_2O_5	2·03
Total	99·69	100·33	100·01				Al_2O_3	·17
								99·95

The ration $SiO_2 : (MgFeMn)O : CaO = 1·00 : 1·02 : 1·00$ is very satisfactory, and gives the usually accepted formula $CaMgSiO_4$ in which a little Mg is replaced by Fe and Mn. A careful test was made for P_2O_5 but none was found, and undoubtedly Genth's material, as assumed by him, was contaminated with apatite. From the crystal from which the material for analysis was taken, a few colorless and transparent grains were selected which when heated in the closed tube gave only the merest trace of water, the pure mineral is therefore practically anhydrous, but in order to obtain sufficient material for the analysis it was necessary to include some slightly brownish grains, and these were permeated with cracks along which decomposition had commenced, which accounts for the water.

For the determination of the optical properties a single crystal like the one figured by Pirsson was used. The indices of refraction, determined by means of prisms, are as follows: for yellow light, Na, $\alpha = 1·6505$, $\beta = 1·6616$, $\gamma = 1·6679$, $\gamma - \alpha = 0·0174$; also β, Li $= 1·6594$ and β, Tl $= 1·6653$. The optical orientation is $a = c$, $b = a$, and $c = b$ as in chrysolite. The plane of the optical axes is 001 and a is the acute bisectrix, consequently the double refraction is negative. The dispersion is $\rho > \upsilon$ as follows: 2H,Li $= 75° 55'$, 2H,Na $= 75° 21'$, and 2H,Tl $= 74° 52$. The measurements being made in α-mono-bromnaphthalene, V_a,Li $= 37° 51'$, V_a,Na $= 37° 31'$ and V_a,Tl $= 36° 28'$, while from the values of α, β and γ as given above V_a,Na by calculation, was found to be $37° 9'$.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, October, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Recent investigations on hydrogen peroxide.*—Our knowledge of the chemical nature of this interesting substance was much advanced by the work of Traube, chiefly recorded in the "Berichte" of the German Chemical Society from 1882 to 1893. Traube came to the conclusion that hydrogen peroxide cannot possess the same constitution as the peroxides of manganese, lead and silver, because it is not produced, like these, at the anode in electrolysis, but is produced along with hydrogen at the kathode, especially when oxygen is blown against this electrode. He considered it, therefore, not an oxidation-product of water, but a reduction-product of molecular oxygen. This view is also supported by the fact that hydrogen peroxide is never formed by the oxidation of hydrogen by nascent oxygen or other oxidizing agents, while, moreover, it reduces all the powerful oxidizing agents or is destroyed by them. Traube therefore rejected the generally-accepted di-hydroxyl formula, HO.OH, and advanced the view that the substance is a hydride of molecular oxygen, as expressed by the formla H[O:O]H.

The interest taken in hydrogen peroxide has been considerably increased since Wolffenstein showed that the substance could be purified and concentrated, with but small loss through decomposition, by distillation under diminished pressure, (Berichte, 1894, 3307). To perform this operation it is necessary that the solution should be free from compounds having an alkaline reaction as well as from every trace of salts of the heavy metals and from solid substances of all kinds. Wolffenstein recommends a simple distillation of the commercial 3 per cent solution under a pressure of about 68^{mm} for the production of small quantities of the pure solution. For larger quantities he advises evaporation at ordinary pressure upon the steam-bath until a concentration of about 20 per cent is reached, then concentration under diminished pressure to 50–55 per cent, after that, extraction with ether (Brühl considers this step dangerous, as will be seen beyond), and finally distillation under diminished pressure. By repeated fractionation he obtained a product which boiled at 84–85° at 65^{mm}, and which contained 99·1 per cent of the substance.

Spring (Zeitschr. anorg. Chem., viii, 424) has prepared large quantities of hydrogen peroxide by Wolffenstein's method and has determined some of its physical properties. He found it to have a blue color about half-again as intense as that of water, and concludes that this fact supports Traube's theory concerning the constitution of the compound, because Olszewski having shown that liquid oxygen has a blue color about fifty times as strong as that of water, he concludes that oxygen retains more of

its original properties in hydrogen peroxide than in water. Spring concludes also, from determinations of the specific heat of hydrogen peroxide, that the potential energy of the elements is not completely used in forming this compound.

Brühl (Berichte, 1895, 2847) has recently described some important work upon the subject under consideration. Using Wolffenstein's process, usually omitting, however, the extraction with ether, he has prepared hydrogen peroxide in a water-free condition. The boiling-point of his purest product was 69·2° at 26^{mm}. He observed that the distilled substance is much more stable than that which is less pure, and that the nearly water-free liquid suffered scarcely any decomposition when kept cool and in a dark place for five or six weeks. Agitation promotes decomposition, as does also an increase in the surface with which the substance is in contact. Sharp points and rough surfaces have a marked action, and when the compound is brought into contact with a ground-glass surface the decomposition is violent. Paper, cloth, wool and asbestus cannot be used for filtering the concentrated liquid; in fact, wool is ignited by contact with a small amount of it. Gun-cotton does not decompose it and can be used for its filtration. Brühl considers the specific gravity of hydrogen peroxide as the best criterion of its purity. The highest specific gravity which he obtained was, $d_4^0 = 1{\cdot}4584$, while a liquid containing 99·48 per cent of the pure substance, according to analysis, had a density of 1·4094. He experienced no trouble from explosions when solutions were concentrated and purified simply by evaporation and distillation, but some material which had been repeatedly treated with ether gave off much gas with an odor of ozone upon distillation, and an oily, colorless residue, which did not volatilize at 100° was left. This fluid, amounting to only 1 or 2^{cc} showed but slight explosive properties when a drop of it was conveyed into a Bunsen flame by means of a platinum spatula; but when a glass rod with a sharply cut end was brought into contact with the remainder, a fearfully violent explosion took place which caused much damage in the laboratory. A part of this particular sample of hydrogen peroxide had previously caused a serious explosion in Spring's laboratory. Brühl believes that the explosive compound is formed by the action of hydrogen peroxide upon ether, but nothing is as yet known concerning its composition.

Having determined the molecular refraction and dispersion of the pure hydrogen peroxide, with the result that the numbers found were much larger than those calculated for di-hydroxyl, Brühl concludes that the oxygens in the compound must have a multiple linking between themselves. This conclusion conforms with Traube's formula, H·O:O·H, but Brühl objects to this on the ground that neither oxygen nor the other members of the same periodic group show trivalence. But since sulphur, selenium and tellurium show tetravalence, and since there is already ground for supposing the existence of tetravalence in oxygen, as,

for example, the existence of Ag_4O and $HCl(CH_4)_2O$, he proposes the formula H·O⋮O·H. The author calls attention to the advantage of tetravalent oxygen in explaining the constitution of carbon monoxide, C⋮O, but he recognizes the fact that this involves the assumption of unsaturated oxygen in all other organic compounds containing this element. He believes, however, that this view presents no greater difficulty than exists at present in regard to trivalent nitrogen and phosphorus and bivalent sulphur.

H. L. W.

2. *On the constitution of water and the cause of its power of dissociation.*—As mentioned in the preceding notice, BRÜHL has advocated the existence of tetravalent oxygen in hydrogen peroxide. He believes that this view throws new light upon the constitution and the behavior of water, to which he gives the H·Ȯ·H, considering it an unsaturated compound. He points out that water shows the criteria of an unsaturated compound in a marked degree, since nearly all bodies combine with it, innumerable hydrates and compounds with water of crystallization exist, and finally it is the most general solvent. He believes, moreover, that the supplementary valences of tetravalent oxygen are the cause of ionization, and of the power of water to dissociate molecular aggregations.—*Berichte deutsch. Chem. Gesell.*, 1895, 2868. H. L. W.

3. *On the action of prolonged, moderate heating upon detonating gas.*—VICTOR MEYER and WILHELM RAUM have investigated the slow combination of oxygen and hydrogen. The theoretical question involved was the view advanced by the representatives of physical chemistry, that a substance having a catalytic action cannot produce a reaction which is not already existent, and that it merely increases the rapidity of such a reaction. On this assumption hydrogen and oxygen, which combine rather rapidly at 500°, must combine to some extent at ordinary temperatures, even though this action may be so slow that it would require hundreds or thousands of years for the production of an amount of water that could be detected, and it is this slow action that is increased to great rapidity by the presence of a catalytic agent, such as finely divided platinum. The authors have attacked the problem by finding the temperature just low enough so that the gases do not react appreciably when heated for several days, then greatly prolonging the time of action at that temperature. It was found that at 300° no water could be detected after ten days' heating, but after heating uninterruptedly for 65 days, water was found to have been formed. The authors conclude from their results that the reaction under consideration is retarded but not stopped by lowering the temperature and that the assumption of action at ordinary temperatures is justified. —*Berichte deutsch. Chem. Gesell.*, xxviii, 2804. H. L. W.

4. *The absorption of nitrogen by metallic lithium in the cold.*—It has been found by H. DESLANDRES that the combination of nitrogen and lithium takes place more readily than has been sup-

posed. He states that the two elements combine in the cold in a manner analogous to the slow absorption of oxygen by phosphorus. The absorption is, moreover, complete, for when the operation is performed in a closed tube, the spectral bands characteristic of nitrogen absolutely disappear. The blackish tarnish produced upon the surface of metallic lithium by exposure to the air appears to prevent the action, hence a fresh surface is necessary.—*Compt. Rend.*, cxxi, 886. H. L. W.

5. *The decomposition of silicates by boric acid.*—In a preliminary notice, P. JANNASCH states that he and H. HEIDENREICH have found the decomposition of silicates for analysis has been accomplished with entire success by the use of boric acid. For this purpose 1^{g} of the finely pulverized silicate is mixed with 5 or 6 parts of the previously dehydrated acid, then the mixture is strongly ignited for 15 or 20 minutes. The resulting fusion is then almost completely soluble in hot water and alcohol, or a considerable quantity of flocculent silicic acid may be left undissolved. This solution is now evaporated to dryness, and the evaporation is repeated after the addition of methyl alcohol and strong hydrochloric acid, in accordance with the observation of Gooch concerning the volatility of methyl borate. The author states that a series of exact silica determinations have been carried out by this method, and he recommends it as much more simple and expeditious, for the analysis of insoluble silicates in general, than the lead carbonate method which has been recently advocated by him.—*Bericht deutsch. Chem. Gesell.*, xxviii, 2822.

6. *Lighting*, Vol. II of Chemical Technology, edited by GROVES and THORP, 8vo, pp. 398, Philadelphia. 1895, (P. Blakiston, Son & Co. $4.00).—The present volume is an elaborate work on applied chemistry dealing with fats and oils, the stearine industry, candle manufacture, the petroleum industry and lamps. The subjects are treated very thoroughly and comprehensively, and the book is supplied with profuse illustrations of excellent character. A subsequent volume will take up the subjects of gas-lighting, electric lighting, etc. H. L. W.

7. *Movable Light phenomena in rarified gases occasioned by Electrical oscillations.*—J. ELSTER and H. GEITEL in the course of an investigation on kathode rays, observed a remarkable movement of the kathode rays which evidently was due to a wave motion. They employed a step-up transformer connected with an alternating machine to produce the electrical discharges and modified Lenard's kathode ray apparatus in certain respects. The kathode rays could apparently be formed in the rarified chamber as if they proceeded from an electrode in the rarified media, entirely apart from the metallic kathode. The streams could be made to extend from one portion of the glass wall of the Geissler tube in a bent form to another portion. The authors conclude from their experiments that the kathode rays are due not to matter repelled from the electrode but to movements of the ether.—*Ann. der Physik und Chemie*, No. 12, 1895.

J. T.

8. *Ratio between the Electrostatic and Electromagnetic units.*—M. D. HURMUZESCA in his measures employed Maxwell's method in which an electrostatic attraction is balanced by an electrodynamic repulsion. The difference of potential at the ends of a resistance, R, was measured by an absolute electrometer, and the current through this resistance by an electro-dynamometer, the movable coil of which was attached to the lever which carried the movable portion of the electrometer. The value obtained was $V=3{\cdot}0005\times10^{10}$ and $V=3{\cdot}0020\times10^{10}$. The author believes that the measurements of the electrical dimensions are correct to one part in three thousand, and that the accuracy in the determination of V is controlled by that of the determination of the ohm. —*Comptes Rendus*, Dec. 2, 1895. J. T.

9. *Discharges of Electricity through Gases.*—If the discharge tube is surrounded by water, alcohol, turpentine and other media the discharge no longer takes place. This effect is not due to conduction. If a point electrified by a Holtz machine is moved near the tube the discharge is facilitated, and the discharges take place under atmospheric pressure.—*Ann. der Physik und Chemie*, No. 12, 1895, pp. 700–716. J. T.

10. *Double Refraction of Electric Waves.*—R. MACK proves that the electric rays through wood undergo double refraction, and that these rays travel with different velocities. The values obtained for the indices of refraction were $N_1=1{\cdot}75$ and $N_2=2{\cdot}15$.—*Ann. der Physik und Chemie*, No. 12, 1895, pp. 717–732. J. T.

11. *Relation between the atom and the charge of Electricity carried by it.*—Prof. J. J. THOMSON, in the course of an important paper, illustrates the phenomena in the electric field in which the movement of the atoms take place by various mechanical and hydrodynamical analogies. In the course of his investigation he employed the transformer of Elihu Thomson, which consists of a species of secondary Ruhmkorf coil, the primary of which is connected in circuit with Leyden jars, the spark of which is blown out. The blowing out apparatus serves, so to speak, as the break for the secondary of few turns wound on this primary. In this way intense electromotive force can be obtained. The author discusses the question of the relative velocities of the negative and positive atoms, and shows that if the negative atoms move more quickly than the positive, then in a discharge tube in a steady state, the pressure at the positive electrode must be higher than that at the negative. In the case, for instance, of a tube 1^{mm} in diameter, 10^{cm} in length, filled with hydrogen at a pressure of one ten-thousandth of an atmosphere, and conveying a current of one ten-thousandth of an ampere, supposing the velocity of the negative atom to be much greater than that of the positive, the pressure at the positive electrode would exceed that at the negative electrode by about twenty per cent.—*Phil. Mag.*, Dec. 1895, pp. 511–544. J. T.

12. *The duration of Electrical Shadows with solid and fluid insulators.*—Electrical shadows produced by the brush discharge of the conductor of a Holtz machine were first noticed by Professor A. W. Wright, who used as the shadow-giving bodies the finger, wire gratings, paper and cork. Holtz has also worked upon this subject, and used for one electrode a metallic point, and for the other a circular metal plate which was covered with a thin layer of silk. The point can be made positive or negative. One can consider the space between both electrodes as a field of electric force, the force lines of which are made visible by the brush discharge. The electric force in this field is not of the same strength, being greatest along the shorter line between the point and the plate. When one brings a dielectric into this field, an electric polarization occurs between the smallest particles, or according to Maxwell's theory, a displacement current arises. The work expended in causing these polarization or displacement effects produces the shadows. The duration of the electric shadows measures the time of the setting up of the polarization effects or the duration of the displacement currents in the dielectric. Quincke has measured this element of time with a large number of dielectrics. There does not seem to be a simple relation between the duration of the electric shadows and the dielectric constants.—*Sitzungsberichte der Academie der Wissenschaften*, Berlin, May 30, 1895. J. T.

13. *A Laboratory Course of Experimental Physics ;* by W. J. Loudon and J. C. McLennan. 8vo, 302 pp. New York and London, 1895 (Macmillan and Co.).—The present volume is the result of the experience of the authors at the University of Toronto in their efforts to provide a suitable course in experimental physics for a large college class. The difficulties that they have met with and try here to overcome are such as many teachers encounter elsewhere and the latter cannot fail to be benefited by their work. The volume is divided into two parts. The first is elementary and gives such experiments as can be performed by beginners, and which require only a knowledge of elementary mathematics. The second part is for advanced students and involves a ready familiarity with the use of the Calculus. In the first portion are given the experiments dealing with the departments of hydrostatics, gases and light, while those belonging to acoustics, heat and electricity are introduced in the second part. Some teachers may find it advantageous to deviate from this rather arbitrary order of subjects. The work as a whole has been very well carried through and is a valuable addition to the available text-books in this department.

14. *Terrestrial Magnetism.* An international quarterly journal published under the auspices of the Ryerson Physical Laboratory, A. A. Michelson, Director. Edited by L. A. Bauer. Vol. I, No. 1. Chicago (The University of Chicago Press. Two dollars a year). —This new journal is to be devoted exclusively to terrestrial magnetism and its allied subjects, as earth currents, auroras,

atmospheric electricity, etc. It thus fills a place never occupied before and it may be safely predicted that under the able editorship of Dr. L. A. Bauer, who has himself made notable original contributions to terrestrial magnetism, it will do much to stimulate research and observation in this important but difficult branch of science. The editor-in-chief will be aided by a large number of associates, both in this country and abroad. The opening number contains the following articles (pp. 1–28): On electric currents induced by rotating magnets and their application to some phenomena of terrestrial magnetism, A. Schuster; die Vertheilung des erdmagnetischen Potentials in Bezug auf beliebige Durchmesser der Erde, A. Schmidt, Gotha; Halley's earliest equal variation chart, reproduced in fac-simile for the first time from a photograph furnished by Thos. Ward, Esq., of the chart in his possession, text by L. A. Bauer. The remainder of the number, pp. 28–54, is occupied by letters to the editors, notes, reviews, etc.

II. Geology and Mineralogy.

1. *U. S. Geological Survey. 16th Annual Report of the Director*, Chas. D. Walcott.—The present director of the United States Geological Survey has succeeded in presenting in printed form to the Secretary of the Interior at the opening of Congress in December a report of the operations of the survey for the year ending June 30, 1895. Although no radical changes either in policy or personnel were made by the new administration of the survey, a few changes have been made in the way of development of its usefulness. Among these changes may be noted the raising of the quality of the topographic maps and adding the representation on the maps hereafter surveyed in the public-land States of the land-subdivisions; the planning of a system of triangulation to supplement that already done by the Coast and Geodetic Survey and by the Geological Survey; the placing of the entire topographic force within the classified service, so as to limit all appointments to men whose qualifications have been tested by an impartial and thorough examination; the obtaining of authority to print the mineral resources as a part of the annual report; and several other important changes. The appropriation for the work of the survey was $421,600, and in the appropriation act separate sums were set apart for the separate departments of the survey. There was in addition the appropriation for printing which was committed to the public printer—and the salaries of the director and his staff of immediate helpers and office needs were provided for by a separate act—thus limiting the discretionary powers of the administration but giving it a more compact and business-like organization. The internal work of the survey is more minutely divided than it was in former years, giving each field party responsibility for its own work, and each geologist now reports directly to the director of the survey. The work of the survey is

distributed in four groups, Geologic, Topographic, Publication and Administration. Under the geologic branch, there are the divisions of Geology, Paleontology, Chemistry, Hydrography and Mineral Resources. The division of geology was conducted by twenty-six field parties, each party in charge of a geologist or assistant geologist who reported directly to the director. Some of the results reached during the year are the following: The Shaler party in New England have developed the facts regarding the coal field in Rhode Island and made experiments tending to prove a practical use for the large stores of anthracite of this region—also a report on the road-building stones of Massachusetts will appear in the accompanying documents. The Dale party was engaged in mapping the areal geology of the roofing-slate belt of New York and Vermont. Valuable scientific information regarding the Devonian and Silurian rocks was developed by the Willis party working at the coal regions of West Virginia and Maryland. The Campbell party developed the fact that in the extension of the Pottsville coal series of Pennsylvania southward into West Virginia the series itself was increased by the addition of lower beds. The Hayes party have done much in the Tennessee, Georgia and Alabama regions to increase the knowledge of the coals, iron ores, manganese, bauxite and phosphate beds of this region. The R. D. Lacoe collection of carboniferous coal plants recently presented to the National Museum by its maker is of great value and has engaged part of Mr. David White's time during the year, he reports it as containing upward of 80,000 specimens of paleozoic plants. Its scientific value is great, as it contains nearly two-thirds of the original specimens described and figured from the carboniferous flora of the United States. The Georgia and Carolina gold belt was examined by the Becker party, notice of the results has already appeared in these pages. The Van Hise party were working in the Lake Superior region; in their survey they used successfully the magnetic needle in tracing the connection between the Marquette and Michigamme iron-bearing formations over an area where the exposures were very rare. Mr. Gilbert's party have done great service in the Colorado region by determining the depth and position of strata which are likely to furnish successful artesian well supplies. Mr. Hill's party in Texas sent in some pure white chalk from the Cretaceous of that region for illustration of this rock from the United States.

Mr. Emmons carried on laborious and extensive underground examinations of the mines of the Leadville region in the preparation of a supplementary report on this important mining district. He reports the probability of developments of new gold deposits along the contacts between the porphyry and limestones, but on account of the great irregularity of the porphyry intrusions it is impossible to locate exactly where the deposits will occur. Valuable results are also reported from the examination of the Oquirrh mountain range of Utah. Gold and silver being found

beneath thin sheets of eruptive rock occupying a geologic horizon which is probably at the base of the carboniferous limestone. The Cripple Creek gold district was examined and reported on by Mr. Cross, and the ore deposits were studied by Prof. Penrose. An important work has been done by Mr. Diller in the preparation of the educational series of rocks. The work is far advanced and with the accompanying bulletin the specimens are expected to be soon ready for distribution. Other valuable results have been accomplished by the Weed and Eldridge parties in the Rocky mountains; by the Chamberlin party on glacial deposits; by the Turner, Lindgren and Lawson parties in the Pacific region. The director personally made a wide reconnaissance survey over the mining fields of the western United States; thus bringing the survey in touch with a large number of persons taking a vital interest in its proceedings. The Paleontological division was cramped in its work by the smallness of appropriations but several parties were in the field and work already begun was continued with as much vigor as was possible under the circumstances.

The division of Hydrography is the continuation of the work originally assigned to the irrigation division of the survey of 1888, and its investigations are now confined to questions of water supply for the arid region including the location and the volume of rivers. The work has been chiefly done under the charge of Mr. Newell; and investigations have been carried on during the year in the States of Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, N. and S. Dakota, Oregon, Texas, Utah, Washington, Wyoming and, to some extent, in the Eastern States.

The "Mineral Resources of the United States" prepared by Dr. Day will hereafter appear as a part of the Director's Annual Report, it will constitute parts iii and iv of the present annual report.

The organization of the topographic branch has been radically changed. It is now consolidated under the name of topographic branch of the survey under the charge of Mr. Gannett, with two divisions, one of triangulation and the other of topography, and the work is classified by region into four sections, as the Atlantic, Central, Rocky mountain and Pacific sections. The work has been pushed forward with renewed energy and precision.

The other departments of the survey are alike in admirable organization, and the report presents a thoroughly business-like account of its work, which indicates that the survey has lost none of the admirable qualities of its former administration, and that its director is as excellent an executive as geologist. H. S. W.

2. *U. S. Geological Survey; recent Publications.*—The following portions of the sixteenth annual report have already appeared: *Sixteenth Annual Report of the Director, 1894–95;* by CHARLES D. WALCOTT, 4°, pt. I, pp. 130, pl. i. The operations and results

of the geologic work are briefly but comprehensively described.* The condition and progress of the topographic work are illustrated by a general map.

A Geological Reconnoissance across Idaho; by GEORGE H. ELDRIDGE, pt. II, pp. 66, 3 pl., 4 figs. Between Salmon City and Boise ten formations besides a great variety of eruptive rocks are noted. The granites and syenites, in part at least, are probably Archæan; the schists are Algonkian. Quartzites are distributed from the Algonkian to the Carboniferous, while the limestones may include both Silurian and Carboniferous. The age of the great calcareous shale series of the Wood River district is undoubtedly Paleozoic and probably Carboniferous. The sandstones and clays are all of Tertiary age and Post-Pliocene gravels are abundant. In the Continental divide the structure is anticlinal, trending northwest and southeast, but at some other points, especially in the western part of the state, the structure lines trend east-northeast.

Mineral Resources of the United States; by DAVID T. DAY, pt. III, Metallic Products, 646 pp., 13 pl., 9 figs., and pt. IV, Non-metallic Products, 735 pp., 6 pl. By an act of Congress the reports on mineral resources, which were heretofore published in separate volumes, are now included in the annual report of the director but the parts are bound separately. Most of the 37 articles contained in these parts are of a statistical nature, but some of them, as for example *Reconnoissance of the Gold Fields of the Southern Appalachians* by G. F. Becker (see this Journal for Jan. 1896, p. 57), and *Bauxite* by C. W. Hayes, pt. III, p. 547, contain valuable contributions to economic geology.†

A Mineralogical Lexicon of Franklin, Hampshire and Hampden Counties, Massachusetts; by B. K. EMERSON. Bulletin No. 126, 8vo, 180 pp., 1 pl., 5 figs. This bulletin gives a condensed history of each mineral species occurring within the area indicated and is conveniently arranged for reference.

The Bear River Formation and its characteristic Fauna; by C. A. WHITE. Bulletin No. 128, 8vo, 108 pp., 11 pls. Its fauna, which is non-marine, consisting of 48 species, is fully illustrated and described. The position of the formation is designated as at or near the base of the Upper Cretaceous series, thus correcting earlier opinions and confirming the author's suggestion as well as the investigations of T. W. Stanton, who published an article upon the same subject in this Journal, III, vol. xliii, pp. 98–115.

Earthquakes in California in 1894; by C. D. PERRINE. Bulletin No. 129, 8vo, 23 pp.

Report of Progress of the Division of Hydrography for the calendar years 1893 and 1894; by F. H. NEWELL. Bulletin No. 131, 8vo, 126 pp. J. S. D.

* See the preceding review.

† Six papers in part I of the Sixteenth Annual Report and five in part II are yet to appear and will be noticed when issued. Parts III and IV are now complete.

3. *Geology of the Green Mountains in Massachusetts;* by RAPHAEL PUMPELLY, J. E. WOLFF, and T. NELSON DALE (U. S. Geol. Survey Monograph, vol. xxiii, 1894), pp. i–xiv, 1–206, pls. 1–23.—This monograph is the result of thorough investigations of the structure, petrography and minute texture of the rocks of a most difficult metamorphosed region, which were begun in 1885, and although the grander features of the interpretation were substantially reached in 1888, later studies have enabled the authors to correct and confirm the interpretations as now published.

The monograph is composed of three separate parts; the first, by Raphael Pumpelly, defines the nature of the problems involved, and their importance and bearing in bridging over from the discrete formations in the western undisturbed regions to the thoroughly metamorphosed schists of the more eastern areas of New England. The chief difficulties lay in the correlation of the continuous series of metamorphosed schists of the Hoosac mountain series with the series of conglomerates, limestones and schists of the Graylock area. Regarding the lower members of the series, Mr. Pumpelly interprets the "transitional coarse gneisses" to be the result of a Cambrian transgression. He imagines the Cambrian transgression to have found an Archæan elevation, forming the western border of an Archæan dry region, and that the rocks of this dry area had become disintegrated the products varied from kaolin and quartz to semi-kaolinized material, and the detritus of sand and pebbles arising from this disintegrated material was deposited with varying proportions of its constituents in a continuous sheet in progressive "transgression" over the previously dry land. Thus quartzite in one place is interpreted as of the same horizon as the gneiss in another. The white gneisses and conglomerates of Hoosac mountain are correlated with the Cambrian quartzite, the albitic schists of Hoosac mountain with both the limestone and schist of the valley. The metamorphism of the Paleozoic rocks is interpreted as intimately connected with the folding which the rocks of the whole region have suffered; but while structural differences are so explained, differences in composition are explained by the exceptional character of the original sediments.

The second part, by J. E. Wolff, "The Geology of Hoosac Mountain and adjacent Territory," gives a petrographic description of the rocks, with beautiful photo-reproductions of the structures of the metamorphic conglomerates, the albitic schists, the Stockbridge limestone and the amphibolites, together with a detailed elaboration of the structural geology of the region. Although this author concludes that the metamorphic rocks are chiefly of detrital origin, he is not prepared to say that the granitoid gneiss is an altered sediment.

Mr. Dale's paper, Part III, "Mount Graylock; its areal and structural geology," is particularly interesting for its application of a microscopic study of the structure of the foliation of the

rocks to the interpretation of the original planes of sedimentation, and therefrom their present deformation. The author says "the key to the structure is in the distinction between cleavage foliation and stratification." He has not only recognized means of detecting these latter by the former, but has produced beautiful illustrations of the principal types of the phenomena, and has formulated a number of general rules for their practical application which have served him in interpreting the original stratigraphical sequence and their present structural relations of the Graylock mountain series. His paper is further enriched by numerous plates illustrating the topography and geological sections of the region.

The three papers together constitute a valuable illustration of modern methods of conducting geological correlation in regions where fossils fail and original structure is masked by later metamorphism. H. S. W.

4. *The Geological Society of America.*—The eighth annual meeting was held in Philadelphia, Pa., beginning Thursday, December 26, 1895, in the Art Department, University of Pennsylvania. The officers of the Society elected for the year 1896 are as follows: President, Joseph LeConte, California; First Vice-President, Charles H. Hitchcock, New Hampshire; Second Vice-President, Edward Orton, Ohio; Secretary, H. L. Fairchild, New York; Treasurer, I. C. White, West Virginia; Editor, J. Stanley-Brown, Washington, D. C.; Councilors, B. K. Emerson, Amherst, Mass., J. M. Safford, Nashville, Tenn.

At the opening session memorials of the four fellows whose death occurred during the past year were read. The memorial of James D. Dana was prepared by Joseph LeConte, that of Henry B. Nason by T. C. Chamberlin, that of Albert E. Foote by George F. Kunz, and that of Antonio del Castillo by Ezsquiel Ordonez.

At the several sessions the following papers were presented:

GEORGE P. MERRILL: Disintegration and decomposition of diabase at Medford, Mass.

CHARLES R. KEYES: The geographic relations of the granites and porphyries in the eastern part of the Ozarks.

J. F. KEMP: Illustrations of the dynamic metamorphism of anorthosites and related rocks in the Adirondacks.

N. S. SHALER: The importance of volcanic dust and pumice in marine deposits; The relations of geologic science to education (Presidential address).

L. V. PIRSSON: A needed term in petrography.

JOHN J. STEVENSON: The Cerrillos coal field of New Mexico.

W. M. DAVIS: Note on the outline of Cape Cod; Plains of marine and subærial denudation.

F. P. GULLIVER: Cuspate fore-lands.

M. R. CAMPBELL: Drainage modifications and their interpretation.

N. H. DARTON: Some fine examples of stream robbing in the Catskill Mountains; Notes on relations of lower members of coastal plain series in South Carolina; Resumé of general stratigraphic relations in the Atlantic coastal plain from New Jersey to South Carolina.

ROBERT BELL: Proofs of the rising of the land around Hudson Bay.

C. R. VAN HISE: Movements of rocks under deformation.

ALFRED C. LANE: Possible depth of mining and boring.
HARRY FIELDING REID: Notes on glaciers.
FRANK LEVERETT: The relation between ice lobes, south from the Wisconsin driftless area; The loess of western Illinois and southeastern Iowa.
G. FREDERICK WRIGHT: High level terraces of the middle Ohio and its tributaries.
H. L. FAIRCHILD: Four great kame areas of western New York.
WARREN UPHAM: Preglacial and postglacial channels of the Cuyahoga and Rocky rivers.
C. H. HITCHCOCK: Paleozoic terranes in the Connecticut valley.
C. WILLARD HAYES: The Devonian formations of the southern Appalachians.
T. C. CHAMBERLIN: The Natchez formations.
ARTHUR KEITH: Some stages of Appalachian erosion.

5. *The Cerrillos Coal Field;* by JOHN J. STEVENSON. (Abstract of a paper presented at the winter meeting of the Geological Society of America.)—This paper describes a small portion of the area formerly known as the Placer coal field, south from the Rio Galisteo and about 25 or 30 miles south from Santa Fe, New Mexico. The only rocks within this area are Laramie and Eruptive. The latter proceed from the laccolite known as the Placer or Ortiz mountains and occur in two sheets separated by about 400 feet of Laramie beds. These sheets, each about 200 feet thick, are intruded between the stratified rocks and follow their dip closely. The rock has been identified by Prof. Kemp as trachyte but closely allied to andesite. The Ortiz or Placer mountains are about two miles from the most southerly locality visited.

The column of Lamarie exposed is not far from 1,000 feet thick and contains several coal beds of economic importance, only three of which are discussed in this paper. The highest bed, about 900 feet from the base of the column and known as the *White Ash*, has been opened at many places along the principal gorge, Coal cañon. At the most northerly mine, the White Ash, its coal is bituminous, containing 39 per cent of volatile combustible, but at the Lucas mine, not more than 3,000 feet further up the cañon, it is anthracite with but 1 per cent of volatile. The interval between these mines contains for the most part coal so crushed as to be practically unmarketable; but as shown in one level of the White Ash mine, the transition from soft to anthracite coal is gradual. Further up the cañon, toward the Ortiz mountains, the coal becomes harder and at one opening resembles the Rhode Island anthracite.

The lower important bed on Coal cañon is the *Cook-White*, which is not mined at present. It shows the same changes, being distinctly anthracite at the old openings up the cañon, but becoming bituminous lower down, where it contains 30 per cent of volatile. A small bed, midway between the *White Ash* and the *Cook-White*, shows no variation, being bituminous at the most southerly point visited, although the *White Ash* is anthracite in the same locality. But this bed is much cut by clay seams and is not continuous. The cause of the metamorphosis of the coal is contact with eruptive rocks. The clay seams of the

smaller bed prevented transmission of the heat and changes in the coal. Actual contact with the molten rock appears necessary to produce change, for the upper sheet of trachyte comes down to within a few feet of the *White Ash* and evidently has no effect upon its composition; the transition from bituminous to anthracite in that coal bed is regular from the north southward under the sheet, and apparently in no greater ratio than in the *Cook-White*, 150 feet lower, which in turn is fully 200 feet above the lower sheet.

6. *Note on the Trap Rock of the Palisades;* by BENJ. SMITH LYMAN (from a letter to the editors, dated Philadelphia, Jan. 7, 1896).—In the January number of this Journal (p. 4), Prof. Wm. M. Davis refers to my recent report on the New Red of Bucks and Montgomery counties, in the Pennsylvania Geol. Surv., final report, vol. iii, p. 2621, for a brief argument of mine against the intrusive character of the trap of the Palisades. It may be worth while, for the benefit of those interested in the subject, to call attention also to a little fuller discussion of the point in the Proceedings of the American Philosophical Society, vol. xxxiii (1894), p. 195. The intrusive character seems to him "undoubtable." To others it seems not only doubtable, but entirely contrary to observed facts. He speaks of the great length (over fifty miles) of the Palisades trap as the only argument against him; and, indeed, it seems to be of itself an invincible one when taken in connection with the other circumstances, such as the soft shaliness of the sedimentary beds, their gentle dip, the great crookedness of the outcrop, and the exact conformity of the trap beds (not a single bed) to the shales, as made thoroughly evident by the topography of the whole region—not merely "rough" conformity, as he conjectures without substantial proof.

It used to be imagined that volcanic rock, or trap, forced its own way, as a solid wedge might, through hitherto unbroken rock beds, separating them and even lifting them up, to open a passage. It is sufficiently incredible that such a passage would adhere to one bedding plane around basins and saddles in soft, gently dipping shales for a distance of fifty miles. But, taking the view that igneous rock in general merely flows into crevices it finds open, it becomes still more inconceivable that they could have opened along a single bedding plane in such shales, with such dips and such an irregular structure, for such a distance.

7. *Missouri Geological Survey.*—The Annual Report for 1894, received November, 1895, contains the 3d biennial Report of the Director, pp. 1–79; the subjects discussed are: The Crystalline Rocks of Missouri, ERASMUS HAWORTH, pp. 81–224—map, and plates xii–xxx, chiefly micro-photo lithographs; Dictionary of Altitudes, by C. F. MARBUT, pp. 225–316; Characteristics of Ozark Mountains, by CHAS. R. KEYES, pp. 317–352, and Coal Measures of Missouri, by GARLAND C. BROADHEAD, pp. 353–395.

8. *Iowa Geological Survey.*—The third Annual Report, 1894, under the present state geologist, SAMUEL CALVIN (pp. 1–467,

plates i–xi, figures 1–54, and 6 geological maps), contains detailed reports upon the geology of counties of Allamakee, Linn, Van Buren, Keokuk, Mahaska and Montgomery, written by several members of the geological corps.

9. *Illinois State Museum of Natural History.*—Bulletin No. 6. Description of New Species of Paleozoic Echinodermata, by S. A. MILLER and WM. F. E. GURLEY, pp. 1–62, plates i–v. Springfield, Ill., April, 1895.

10. *Geological Survey of Canada.*—The second part of the third volume of "Paleozoic Fossils" was published September, 1895 (pp. 45–128, plates ix–xv), and contains the following papers by J. F. WHITEAVES, viz: 2. Revision of the fauna of the Guelph formation of Ontario, with descriptions of a few new species. 3. Systematic list, with references, of the fossils of the Hudson River or Cincinnati formation of Stony Mountain, Manitoba.

11. *A needed Term in Petrography*, by L. V. PIRSSON. (Abstract of paper read at the winter meeting of Geological Society of America.)—The term crystal when properly used carries with it essentially the idea of an outward geometric form bounded by planes arranged according to certain laws of symmetry, though it implies also a certain interior molecular structure with definite physical properties. There is thus at present no good term to express the formless or rounded masses in which minerals occur, especially in eruptive rocks, and which possess the interior molecular structure of crystals though not their outward form. For such formless or rounded masses the term *anhedron* (without planes) is proposed, and such mineral masses may also be spoken of as having an anhedral development.

12. *Manual of Lithology*, by E. H. WILLIAMS, 2d ed., revised and enlarged, 8°, 418 pp., 6 plates. New York, 1895 (Wiley Pub.). —In this new edition of his little manual Prof. Williams has so greatly enlarged and in so many details changed the character of the work that it bears little resemblance to the former edition. After a short introduction and discussion, the chief rock-making minerals are described; then follows an explanation of the terms (of structure, etc.) used in lithology, which is succeeded by the description of the different kinds of rocks, which comprises all three groups, the igneous, sedimentary and metamorphic. The volume closes with a scheme for determining rocks by their megascopic character combined with physical and chemical tests.

In the brief limits of this notice it is impossible to give any extended review of the work. We note, however, that the proposed basis of classification for the igneous rocks, based as it is on the predominance of the ferro-magnesian silicate present, must present so many uncertainties, together with some absolute contradictions, that it is scarcely probable that it will be generally adopted. We notice also in places obscurities in the author's style which render it difficult to ascertain his precise meaning.

L. V. P.

13. *Handbuch der Mineralchemie;* von C. F. RAMMELSBERG, Zweite Ergänzungsheft zur zweiten Auflage. 8vo, 478 pp. Leipzig, 1895. (Wilhelm Engelmann.)—This second supplement to the second edition of Rammelsberg's great work on *Mineralchemie*, follows the first after the long interval of nearly ten years. During this period many important additions have been made to the literature of mineral chemistry and much progress has been made in the knowledge of the composition of rare species. All of this material has now been collated and worked over by the veteran mineral chemist. The work follows the same line as its predecessor by the same author. His suggestions are based in each case on careful thought and new calculations and always deserve respectful consideration, but many will not follow him in some of his conclusions; for example, in his sweeping refusal to accept the idea that hydroxyl (OH) may replace fluorine in a mineral compound, nor his explanation that in such cases the water yielded on analysis (e. g. topaz, herderite, amblygonite) is due to gradual alteration.

III. BOTANY.

1. *Plant-breeding. Being five lectures upon the amelioration of domestic plants;* by L. H. BAILEY. (Macmillan & Co., 1895.). —Professor BAILEY, of Cornell University, gives in this handy work, of less than three hundred pages, sufficiently explicit directions to guide any person of ordinary judgment in the interesting task of crossing plants. While we miss in its pages references to the very important work by Nägeli, we find enough of essentially the same method of treatment to give the volume high value, not only as a practical treatise, but also as stimulating speculation. The hand-book can be heartily recommended to all classes of persons interested in living plants. G. L. G.

2. *Tubercles on the roots of the Soja bean.*—Professor KIRCHNER (Cohn's Beiträge zur Biol. der Pflanzen, xvii, 2, 1895) has conducted a few remarkably interesting experiments in regard to the production and character of these swellings. When the Soja beans were cultivated in good soil, such as one would ordinarily employ for experimental purposes, no conspicuous tubercles were formed, but when to this soil was added a small amount of earth brought from Japan, and presumably infected with the bacteria associated with the plant, tubercles were abundantly formed, and the plants grew more thriftily than under previous conditions. The soil came from Japan in well-soldered metallic boxes. It was black, uncommonly light, volcanic ash. It was moist when it arrived, and contained fragments of the roots of the Soja plants which had been cultivated therein.

While the observation is not wholly new, it confirms some kindred results, and tends to open up still farther the possibility of more successful cultivation of *Papilionaceæ* in infected soil. GONNERMANN (Land w. Jahr b. xxiii, 1894) has apparently

demonstrated that root tubercles are not produced by only one species of bacterium, varying, as some have thought, according to the kind of soil in which they occur.

Although much advance has been made in the direction of settling some of these disputed points, a great deal remains to be learned in regard to turning the observations to practical account. Two of our southern plants, the so-called "Cow-pea," in its multiform varieties, and *Arachis*, appear to be the best subjects of research in this department. The increasing utility of the former as a direct or indirect fertilizer, and of the latter in its new applications in the production of a food, after the extraction of the oil, indicates the desirability of experiments at the southern stations. G. L. G.

3. *Modifications of the Cell-wall.*—There are two recent communications relative to changes in the cell-wall which may be conveniently considered together. VAN WISSELINGH points out numerous differences between the formation and character of Suberin and Cutin, of which we here recount only the most important. Suberin is always laid down at a later period than Cutin, and appears on the inner side of the cell-wall, in direct contact with protoplasmic matter, whereas Cutin arises on the outside of epidermal cells, and possesses between itself and the protoplasm a layer of well-marked cellulose. Suberin is more easily saponified by potassic hydrate that Cutin is, and the products of saponification differ in appearance from those arising from Cutin.

The other paper deals with the mucilaginous modification of the walls of cells. MANGIN (Bulletin Soc. Fr., xli) classifies mucilages into simple and complex, dividing the former again into (1) cellulose mucilages; which are rather rare (a good example is afforded by Salep), (2) pectose mucilages, common in *Malvaceæ*, *Tiliaceæ*, and certain algæ; (3) callose mucilages, confined in the higher plants to the sieve tubes. The second group of mucilages, the mixed, or complex, belong to various seeds. Here we find the cellulose and pectose-mucilages commingled in different amounts.

According to Guiraud, the mucilage in *Malvaceæ* is found to some extent in all organs, and comes from the breaking down of the walls of certain cells in the secondary parenchyma. It may be retained in special cells, or it may overflow from them.

The existence of nitrogen in the so-called mucilage of at least two species of *Dioscorea* may be regarded as settled by the work of ISHII, of Japan. The mucin here found is essentially like that occurring in animals. G. L. G.

4. *On the accumulation of sugar in the root of the Beet.* (Comptes Rend., 2 Dec. 1895.)—L. MAQUENNE calls attention to the difficulty of explaining the equilibrium which exists between the leaves and the root of beets, considering the chemical composition of the two. It is easy to understand how the carbhydrates elaborated by the chlorophyll-bearing cells reach the root by

diffusion; but it is not so easy to tell why, after taking the form of sugar, these carbhydrates do not return to the leaves again, in virtue of the very same laws of diffusion. Since uniformity does not exist between the chemical composition of cell-contents in different parts of the plant, diffusion must be assumed to be balanced by some other force. The author regards this as a simple question of osmotic balance. Applying the doctrine of osmotic equivalents to the special case in hand, he states that the saccharose in the root, to satisfy the demands of existing conditions, should be, in concentration, double that of the reducing sugars found in the leaves. Further, a similar equilibrium may be supposed to exist between the root and the soil. MAQUENNE'S recorded results are suggestive from many points of view. From them he enunciates the following law, which he regards as of general applicability to Physiology,—any immediate principle can accumulate whenever its formation gives rise to a reduction of osmotic pressure. It is interesting to notice that this substantially restates a law applied by DEHERAIN to the appropriation of mineral matters and the transfer of elaborated substances in plants. G. L. G.

5. *Guide to the British Mycetozoa;* by ARTHUR LISTER, pp. 42, fig. 44.—This little book is the second of the botanical series intended to serve as a guide to specimens exhibited in the British Museum. It gives a condensed account of British Mycetozoa taken from the author's monograph of the Mycetozoa, of which a notice was given a few months ago, preceded by a short account of the general structure and development of the order. The collection of British Mycetozoa and the series of colored drawings explaining their structure, now exhibited in the botanical gallery of the Museum, were presented by Mr. Lister, as well as over eight hundred mounted slides kept in a cabinet of the cryptogamic herbarium. This valuable collection, taken in connection with Mr. Lister's guide, will make it comparatively easy for students to recognize British species of this difficult order.

W. G. F.

6. *The Norwegian Forms of Lithothamnion;* by M. FOSLIE, pp. 180, 8°, pl. 23. Trondhjem, 1895.—In this elaborate monograph the author gives a critical study of the species of Lithothamnion and Lithophyllum of northern Europe, with occasional references to species of North America. Our knowledge of the confused species of the Corallinaceæ comprised in the Lithothamnion group has been much increased in recent years owing to the writings of Kjellman, Rosenvinge, Strömfelt and Foslie. The present paper is a revision of previous papers in the light afforded by fresh material from America as well as Europe. The writer reduces Lithophyllum to a subgenus of Lithothamnion, instead of regarding it as most closely related to Melobesia, where it was placed by Batters and ourselves; and the subgenus Eulithothamnion he divides into two sections, Innatæ, with innate, and Evanidæ, with superficial sporangial conceptacles. The definition of species in algæ of this

group is always a difficult matter, for both sporangia and cystocarps are often wanting, and the habit of the thallus depends upon the place of growth and the surroundings. Furthermore, the older descriptions were frequently very vague and incomplete. The author has reduced a number of the species of previous Scandinavian writers to synonyms, but has created a number of new species, so that we now have the surprising number of thirty-nine species in the region studied. Apart from Greenland species, the North American species noted are L. fruticulosum (Kütz) Fosl., and L. colliculosum Fosl., to which are referred the L. fasciculatum of Farlow's Marine Algæ of New England; L. flabellatum Rosenv., to which is doubtfully referred a sterile specimen found by Collins in Maine; L. compactum Kjellm., the common New England form usually referred to L. polymorphum; L. evanescens Fosl., collected by Collins at Marblehead, Mass.; L. lævigatum Fosl., from Kennebunkport, Me., Collins; and L. Strömfeltii Fosl., and L. Lenormandi (Phil.) Fosl., to which is referred in part the Melobesia Lenormandi of Farlow's Marine Algæ of New England. The habits of the different species are given in twenty-three good photo-lithographic plates. The monograph closes with a short chapter on Fossil Lithothamnia.

W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *The composition of expired air and its effects upon animal life;* by J. S. Billings, M. D., S. Weir Mitchell, M. D., and D. H. Bergey, M. D.—A memoir bearing the above title has been recently issued in the series of Smithsonian Contributions to Knowledge, No. 989. It gives the result of investigations carried on under a grant from the Hodgkins Fund of the Smithsonian Institution, for the purposes of determining the nature of the peculiar substances of organic origin contained in the air expired by human beings, with special reference to the practical application of the results obtained to problems of ventilation of inhabited rooms. The conclusions contain so much of general interest that they are printed here in full:

I. The results obtained in this research indicate that in air expired by healthy mice, sparrows, rabbits, guinea-pigs, or men, there is no peculiar organic matter which is poisonous to the animals mentioned (excluding man), or which tends to produce in these animals any special form of disease. The injurious effects of such air observed appeared to be due entirely to the diminution of oxygen, or the increase of carbonic acid, or to a combination of these two factors. They also make it very improbable that the minute quantity of organic matter contained in the air expired from human lungs has any deleterious influence upon men who inhale it in ordinary rooms, and hence it is probably unnecessary to take this factor into account in providing for the ventilation of such rooms.

II. In ordinary quiet respiration, no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. In the act of coughing or sneezing, such organisms or particles may probably be thrown out.

III. The minute quantity of ammonia, or of combined nitrogen, or other oxidizable matters found in the condensed moisture of human breath, appears to be largely due to products of the decomposition of organic matter which is constantly going on in the mouth and pharynx. This is shown by the effects of cleansing the mouth and teeth upon the amount of such matters in the condensed moisture of the breath, and also by the differences in this respect between the air exhaled through a tracheal fistula and that expired in the usual way.

IV. The air in an inhabited room, such as the hospital ward in which experiments were made, is contaminated from many sources besides the expired air of the occupants, and the most important of these contaminations are in the form of minute particles, or dust. The experiments on the air of the hospital ward, and with the moisture condensed therefrom, show that the greater part of the ammonia in the air was probably connected with dust particles which could be removed by a filter. They also showed that in this dust there were micro-organisms, including some of the bacteria which produce inflammation and suppuration, and it is probable that these were the only really dangerous elements in this air.

V. The experiments in which animals were compelled to breathe air vitiated by the products of either their own respiration or by those of other animals; or were injected with fluid condensed from expired air, gave results contrary to those reported by Hammond, by Brown-Séquard and d'Arsonval, and by Merkel, but corresponding to those reported by Dastre and Loye, Russo-Giliberti and Alessi, Hoffmann-Wellenhof, Rauer, and other experimenters referred to in the preliminary historical sketch of this report, and make it improbable that there is any peculiar volatile poisonous matter in the air expired by healthy men and animals, other than carbonic acid. It must be borne in mind, however, that the results of such experiments upon animals as are referred to in this report may be applicable only in part to human beings. It does not necessarily follow that a man would not be injured by continually living in an atmosphere containing two parts per 1000 of carbonic acid and other products of respiration, of cutaneous excretion, and of putrefactive decomposition of organic matters, because it is found that a mouse, a guinea-pig, or a rabbit seems to suffer no ill effects from living under such conditions for several days, weeks, or months; but it does follow that the evidence which has heretofore been supposed to demonstrate the evil effects of bad ventilation upon human health should be carefully scrutinized.

VI. The effects of reduction of oxygen and increase of carbonic acid to a certain degree appear to be the same in artificial

mixtures of these gases as in air in which the change of proportion of these gases has been produced by respiration.

VII. The effect of habit, which may enable an animal to live in an atmosphere in which, by gradual change, the proportion of oxygen has become so low, and that of the carbonic acid so high, that a similar animal brought from fresh air into it dies almost immediately, has been observed before, but we are not aware that a continuance of this immunity produced by it had been previously noted. The experiments reported in the Appendix, VII, 17 to 28, show that such an immunity may either exist normally or be produced in certain mice, but that these cases are very exceptional, and it is very desirable that a special research should be made to determine, if possible, the conditions upon which such a continuance of immunity depends.

VIII. An excessively high or low temperature has a decided effect upon the production of asphyxia by diminution of oxygen and increase of carbonic acid. At high temperatures the respiratory centers are affected, where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture; at low temperatures the consumption of oxygen increases, and the demand for it becames more urgent.

So far as the acute effects of excessively foul air at high temperatures are concerned, such, for example, as appeared in the Black Hole at Calcutta, it is probable that they are due to substantially the same causes in man as in animals.

IX. The proportion of increase of carbonic acid and of diminution of oxygen, which has been found to exist in badly ventilated churches, schools, theatres or barracks, is not sufficiently great to satisfactorily account for the great discomfort which such conditions produce in many persons, and there is no evidence to show that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death-rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms. The report of the commissioners appointed to inquire into the regulations affecting the sanitary conditions of the British army (1), properly lays great stress on the fact that in civilians at soldiers' ages, in twenty-four large towns, the death-rate per 1000 was 11.9, while in the foot-guards it was 20.4, and in the infantry of the line 17.9, and showed that this difference was mainly due to diseases of the lungs occurring in soldiers in crowded and unventilated barracks. These observations have since been repeatedly confirmed by statistics derived from other armies, from prisons, and from the death-rates of persons engaged in different occupations; and, in all cases, tubercular disease of the lungs and pneumonia are the diseases which are most prevalent among persons living and working in unventilated rooms, unless such persons are of the Jewish race. But consumption and pneumonia are caused by specific bacteria, which, for the most part, gain access to the air-passages by adhering to particles of dust which are inhaled,

and it is probable that the greater liability to these diseases of persons living in crowded and unventilated rooms, is, to a large extent, due to the special liability of such rooms to become infected with the germs of these diseases. It is, however, by no means demonstrated as yet, that the only deleterious effect which the air of crowded barracks or tenement-house rooms, or of foul courts and narrow streets, exerts upon the persons who breathe it, is due to the greater number of pathogenic micro-organisms in such localities. It is quite possible that such impure atmospheres may affect the vitality and the bacterioidal powers of the cells and fluids of the upper air-passages with which they come in contact, and may thus predispose to infections, the potential causes of which are almost everywhere present, and especially in the upper air-passages and in the alimentary canal of even the healthiest persons, but of this we have as yet no scientific evidence. It is very desirable that researches should be made on this point.

X. The discomfort produced by crowded, ill-ventilated rooms in persons not accustomed to them, is not due to the excess of carbonic acid, nor to bacteria, nor, in most cases, to dusts of any kind. The two great causes of such discomfort, though not the only ones, are excessive temperature and unpleasant odors. Such rooms as those referred to are generally overheated, the bodies of the occupants and, at night, the usual means of illumination contributing to this result.

The cause of the unpleasant, musty odor which is perceptible to most persons on passing from the outer air into a crowded, unventilated room is unknown; it may, in part, be due to volatile products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, or certain disorders of the digestive apparatus, and it is due, in part, to volatile fatty acids given off with, or produced from, the excretions of the skin, and from clothing soiled with such excretions. It may produce nausea and other disagreeable sensations in specially susceptible persons, but most men soon become accustomed to it, and cease to notice it, as they will do with regard to the odor of a smoking-car, or of a soap factory, after they have been for some time in the place. The direct and indirect effects of odors of various kinds upon the comfort, and perhaps also upon the health of men, are more considerable than would be indicated by any tests now known for determining the nature and quantity of the matters which give rise to them. The remarks of Renk (38, p. 174) upon this point merit consideration. Cases of fainting in crowded rooms usually occur in women, and are connected with defective respiratory action due to tight lacing or other causes.

Other causes of discomfort in rooms heated by furnaces or by steam are excessive dryness of the air, and the presence of small quantities of carbonic oxide, of illuminating gas, or of arsenic derived from the coal used for heating.

XI. The results of this investigation, taken in connection with the results of other recent researches summarized in this report,

indicate that some of the theories upon which modern systems of ventilation are based, are either without foundation or doubtful, and that the problem of securing comfort and health in inhabited rooms requires the consideration of the best methods of preventing or disposing of dusts of various kinds, of properly regulating temperature and moisture, and of preventing the entrance of poisonous gases like carbonic oxide, derived from heating and lighting apparatus, rather than upon simply diluting the air to a certain standard of proportion of carbonic acid present.

It would be very unwise to conclude from the facts given in this report, that the standards of air-supply for the ventilation of inhabited rooms, which standards are now generally accepted by sanitarians as the result of the work of Pettenkofer, De Chaumont and others, are much too large under any circumstances, or that the differences in health and vigor between those who spend the greater part of their lives in the open air of the country hills, and those who live in the city slums, do not depend in any way upon the differences between the atmospheres of the two localities except as regards the number and character of micro-organisms.

2. *Report of the Agricultural Experiment Stations of the University of California, for the year 1892-3 and part of 1894, being a part of the Report of the Regents of the University. Sacramento State Office, 1894.*—This volume of 506 pages is the most recent of a dozen very valuable Reports on the instruction and investigations undertaken by Prof. E. W. Hilgard and his colleagues. Besides the central experiment station at Berkeley, seven branch stations in various parts of California are carried on, the station staff consisting of eight scientists (also professors and instructors in the university) and twelve foremen. As California, with one exception, exceeds all other States of our Union in area and surpasses all in variety of soil, climate and vegetation, so she takes the lead in investigating the questions of science and practice which are involved in her agriculture.

In the introduction, Prof. Hilgard who, with leave of absence, spent the year 1892–3 in Europe, gives an interesting "report of observations on European agricultural schools and experiment stations." He found the agricultural university at Berlin with a faculty of fourteen professors, sixteen assistants and fifteen instructors, and using buildings and equipment that cost $632,000, exclusive of extensive museum collections. Of the 400 students in annual attendance, 200 were taking instruction in surveying and agricultural engineering; about 50 were fitting for government employment as clerks and fiscal officers, while 150 were agricultural students strictly considered, aiming to be managers of or employés on large estates.

Part I is a report and discussion of work in the general agricultural laboratories, comprising highly interesting researches into the chemical and mechanical composition and physical characters of soils, by Messrs. Hilgard, Loughridge and Jaffa; special

study and reclamation of alkali soils, by Messrs. Hilgard, Colemore and Shinn; analysis of seventy natural waters, by Messrs. Jaffa and Curtis; chemical composition of various foods and fruits, by Messrs. Colby and Jaffa; an elaborate paper on olives, olive culture and olive oil, by Mr. Hayne; and one on the ash of grapes and fertilization of vineyards, by Mr. Bioletti.

Prof. Hilgard contributes important papers on nitrogen-contents of soil humus in arid and humid regions; on influence of climate upon the formation and composition of soils; the Cienegas of southern California; crops and fertilizers with reference to California soils and practice; fruits and fruit soils in the arid and humid regions.

Part II is occupied with reports of culture work at the several stations by Messrs. Wickson, Shinn, Kellner, Davy, Tyson, and Forrer.

Part III, by Prof. Woodworth, is devoted to entomology and plant diseases.

This volume altogether is one of great scientific and practical value. S. W. J.

3. *Dark companion to one of the components of the binary star 70 Ophiuchi.*—The star 70 Ophiuchi is composed of two components of the 4th and 6th magnitudes severally, whose greatest distance is less than 7 seconds. The period of rotation is about 90 years. The brightness of the components and their comparatively rapid angular motion make this system one of peculiar interest, and numerous computed orbits for it have been published. Professor See of Chicago University, in No. 363 of the Astronomical Journal (Jan. 1896), from an elaborate discussion of the measures made since Herschel in 1779 discovered that it was a double star, concludes that there must be a dark companion to one of the components. The deviations from pure elliptic motion seem to indicate quite unmistakably the existence of such dark body.

BOOKS AND PAMPHLETS RECENTLY RECEIVED AND THUS FAR NOT OTHERWISE NOTICED.

Contribution a l'Étude des Lapiés.—La topographie du désert de Platé (Haute-Savoie); par ÉMILE CHAIX. (Extr. du GLOBE, Journal géographique organe de la Société de Géographie de Genève, tom. xxxiv), pp. 1–44. plates i–xvi, 1895.

Soils of Illinois; by FRANK LEVERETT. (Extracted from Final Report, Ill. Board World's Fair Com.), pp. 77–92, 1895.

Preglacial Valleys of the Mississippi Tributaries; by FRANK LEVERETT. (Journ. Geol., vol. iii, Oct.–Nov., 1895), pp. 740–763, 1895.

The duration of Niagara Falls and the History of the Great Lakes; by J. W. SPENCER, pp. 1–126, figs. 1–27, plates i–v. Humboldt Publishing Co., New York, 1895.

Geographical Evolution of Cuba; by J. W. SPENCER. (Extr. Bull. Geol. Soc. Am, vol. vii,) pp. 67–94, Dec., 1895.

Clay Industries of New York, prepared under the direction of FREDERICK J. H. MERRILL, by HEINRICH RIES. (Extr. N. Y. State Museum, vol. iii), pp. 96–262, illustrated, 1895.

The Animal Nature of Eozoön; by Sir WILLIAM DAWSON, C.M.G., LL.D., F.R.S., etc. (Extracted from the Geological Magazine, October, November, December.) London: Dulau & Co., 37 Soho Square, W.

Geology of Moriah and Westport townships, Essex Co., N. Y., with a Geol. map, prepared under the direction of FREDK J. H. MERRILL; by J. F. KEMP. (Extr. Bull. N. Y. State Mus, vol. iii,) pp. 323–355. Sept., 1895.

Preliminary Report on the Geology of Essex Co., N. Y.; by J. F. KEMP. (Extr. Rept. State Geol. for year 1893), pp. 431–472. 1895.

On a well-marked horizon of Radiolarian rocks in the lower Culm measures of Devon, Cornwall, and West Somerset; by G. J. HINDE and HOWARD FOX. (Extr. Quart. Jour. Geol. Soc., vol. li), pp. 609–668, plates xxiii–xxviii. Nov., 1895.

On a new species of Diplacodon, with a discussion of the relations of that genus to Telmatotherium, and

Discovery, in the Oligocene of South Dakota, of Eusmilus, a genus of Sabre-toothed Cats new to North America; by J. B. THATCHER. (Extr. Am. Nat., pp. 1084–1093, plates xxxviii–xl. Dec., 1895.)

Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains; by GEORGE M. DAWSON with the collaboration of R. G. McConnell. (Extr. Bull. Geol. Soc. Am., vol vii), pp. 31–66, pl. 1, Nov., 1895.

On the Structure and Development of the vertebral column of Amia; by O. P. HAY. (Extr. Field Columbian Museum, Publication 5, Zool. Series, vol. i, No. 1), pp. 1–54, pls. i–iii. Oct., 1885.

On certain portions of the skeleton of Protostega gigas; by O. P. HAY. (Extr. Field Columbian Mus., Publ. 7, Zool. Ser., vol. i, No. 2), pp. 57–62, pls. iv, v, Nov., '95.

Ueber das Alter der thüringer Tentaculiten- und Nereiten-Schichten; von E. KAYSER. (Extr. Zeitschr. d. Deutsch. geol. Gesellschaft, 1894, heft 4), pp. 823–827, 1895.

Ueber das Alter von Myalina bilsteinensis, von E. KAYSER. (Extr. Jahrb. d. Königl. preuss. geol. Landesanstalt f. 1894), pp. 122–138, pls. iii–iv, 1895.

Sur une faune du Sommet de la série Rhénane, a Pepinster, Goé et Tilff; par E. KAYSER. (Extr. Ann. de la Soc. géol. de Belg, t. xxii), pp. 175–216, pls. 1–4. 1895.

A contribution to the neocene corals of the United States; by H. S. GANE. (Extr. Johns Hopkins Univ. Circ'ls., No. 121, Oct., 1895.

The neocene of the Santa Cruz Mountains. 1. Stratigraphy; by GEORGE H. ASHLEY. (Extr. Proc. Cal. Acad. Sci., Series 2, vol. v), pp. 273–367, pls. xxii–xxv. 1895.

Edward Hitchcock; by C. H. HITCHCOCK. (Extr. Am. Geol., vol. xvi), pp. 133–149, pl. vii, Sept., 1895.

Edward Hitchcock. (Obituary notice with portrait. Extr. Pop. Sci. Monthly, Sept., 1895.)

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Grundzüge der marinen Tiergeographie, Anleitung zur Untersuchung der geographischen Verbreitung mariner Tierre, mit besonderer Berücksichtigung der Dekapodenkrebse; von Dr. ARNOLD E. ORTMANN in Princeton, N. J., Mit Karte. Jena: Verlag von Gustav Fischer, 1896.

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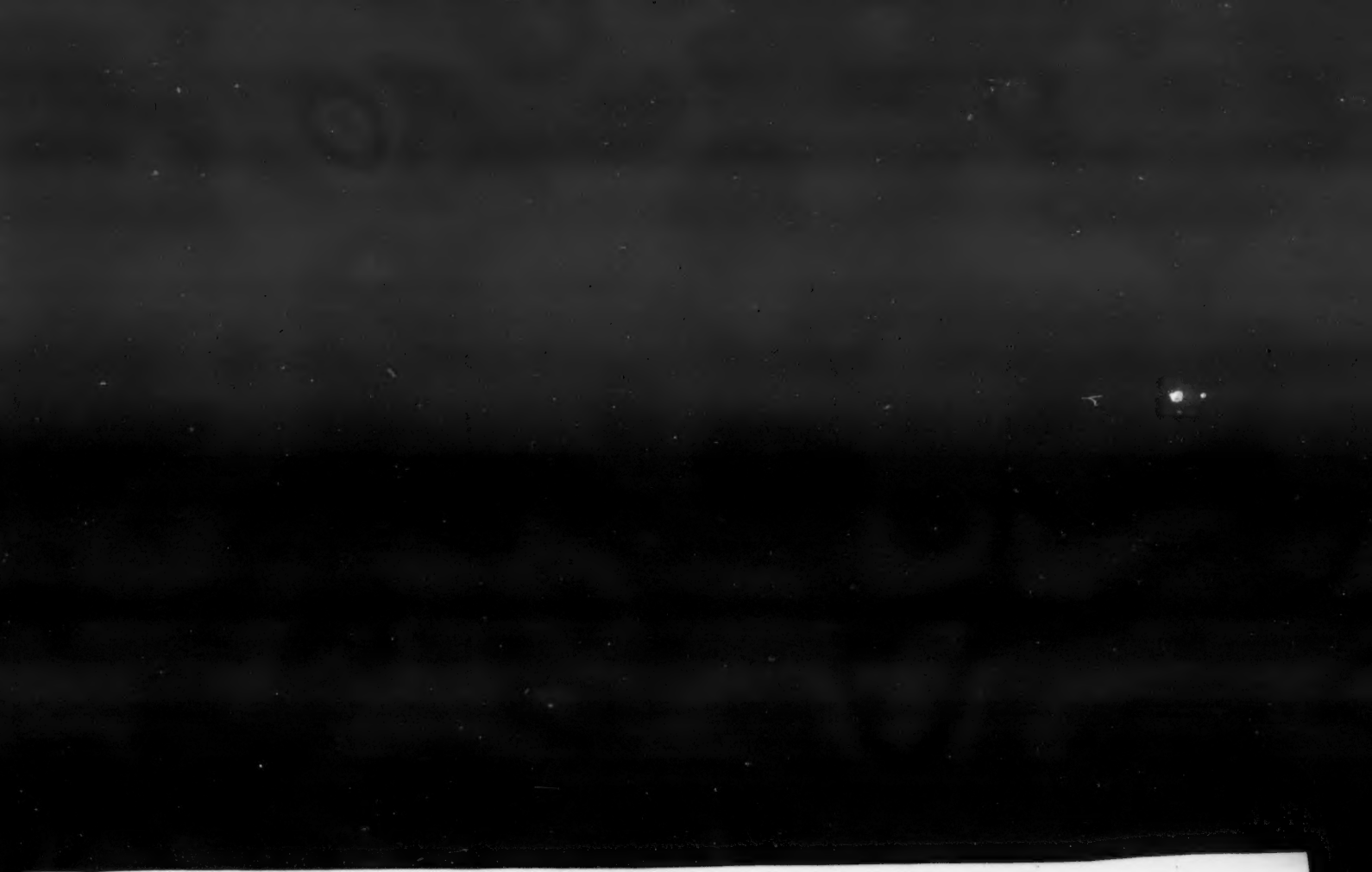
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